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THE HIMALAYA AS A BARRIER TO MODERN COMMUNICATIONS : *A paper read at the Evening Meeting of the Society on 4 November 1935, by*

PROFESSOR KENNETH MASON

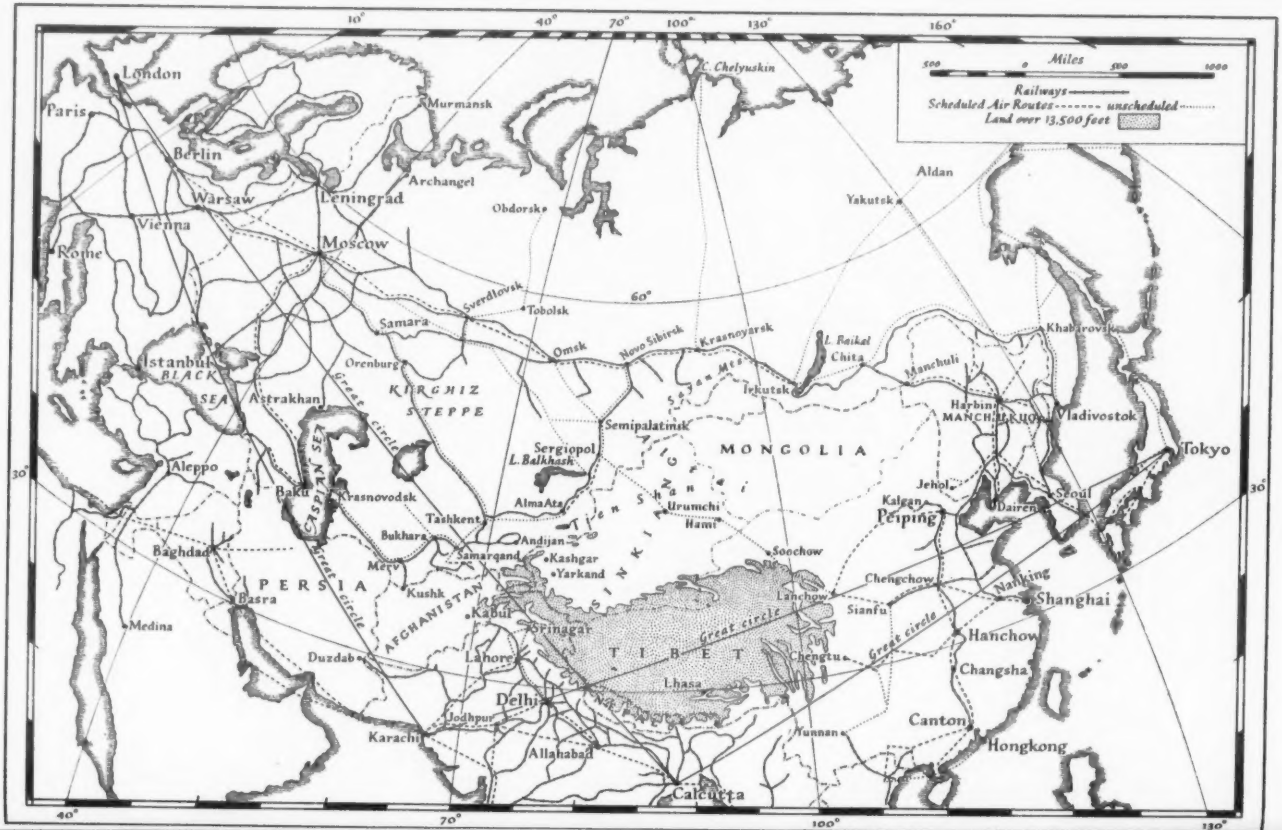
(Sixth Asia Lecture)

THE title of my Asia Lecture was suggested by the growth of modern communications across Asia during the last ten or fifteen years, and by a feeling that it would be well to get our ideas clear on the question whether the Himalaya can be considered a barrier to communication in the immediate future, as it has been throughout historical times.

The position before the Great War was this: India, the "keystone of the Indian Ocean," as it has been called, communicated with the West and East by means of the two sea corridors, the Suez Canal and the Straits of Malacca, and to a less extent by South Africa and southern Australia. For her prosperity she looked seawards through her four ports, Calcutta, Bombay, Madras, and Karachi. A little trade trickled across her land frontiers—by Seistan and across the Khyber Pass on the backs of camels to Kabul and beyond, and an almost insignificant amount crossed the Himalayan passes to Chinese Turkistan and Tibet, on ponies, sheep, or yak.

North of the mountains of Central Asia, north of the Altai and Sayan mountains, north of the deserts of Mongolia, there was the great Trans-Siberian Railway, a single track, connecting Moscow, through Omsk, by Lake Baikal and Manchuria, with Vladivostok. At Samara a second line branched south-eastwards across the Kirghiz Steppe and by the valley of the Syr Darya to Tashkent, while the Trans-Caspian railway linked up Krasnovodsk, Merv, Bukhara, Samarqand, and terminated at Andijan. These last two were joined together south of Tashkent, and two important branch lines led southwards to Kushk and Termez on the Afghan frontier. They were mainly strategic, and it cannot be said that they carried a great deal of trade, either with Afghanistan or with Sinkiang. But from Russian Turkistan there was some rather primitive trade with Kashgar and Yarkand.

The disasters of the Russo-Japanese War of 1904–05, and the increasing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unsettlement at home, had called a halt to Russia's expansion in Asia, and a convention between Britain and Russia in 1907 had settled the outstanding questions of interest regarding the status of Tibet, Afghanistan, and Persia. Almost for the first time in history the two countries were working in harmony and cooperation in Asia, and in 1913, after three years of scientific collaboration, the trigonometrical surveys of India and Russia were linked on the Pamirs.

The reorganization of the Russian Empire after the revolution brought about great changes in Asia. The Imperial province of Russian Turkistan was split up into various Soviet republics, organized, it was claimed, on racial and ethnological lines. Plans for the self support of the U.S.S.R. meant, in theory at least, that each state of the Union should be developed according to its individual capacity, in order to contribute to the Union as a whole. The tendency has been to create industrial centres at the sites of raw material, rather than to bring the raw material back to old industrial centres in Europe. The growing industrial centres in Asia have brought in their train increased agricultural development. There is, in fact, a shifting of Russian effort from Europe to Asia, with a consequent need for the development of communications in Asia. This development has been considerably speeded up during the period of the "Second Five-Year Plan."

But, while Russia's grip over her own territory has been tightened, China's has been loosened over hers. Mongolia and Manchuria have broken away, one with the connivance of Russia, the other with the encouragement of Japan; and since the war until very recently, there has been little security or stability in Chinese Central Asia. In consequence, there has been little railway development except in the Russian and Japanese spheres.

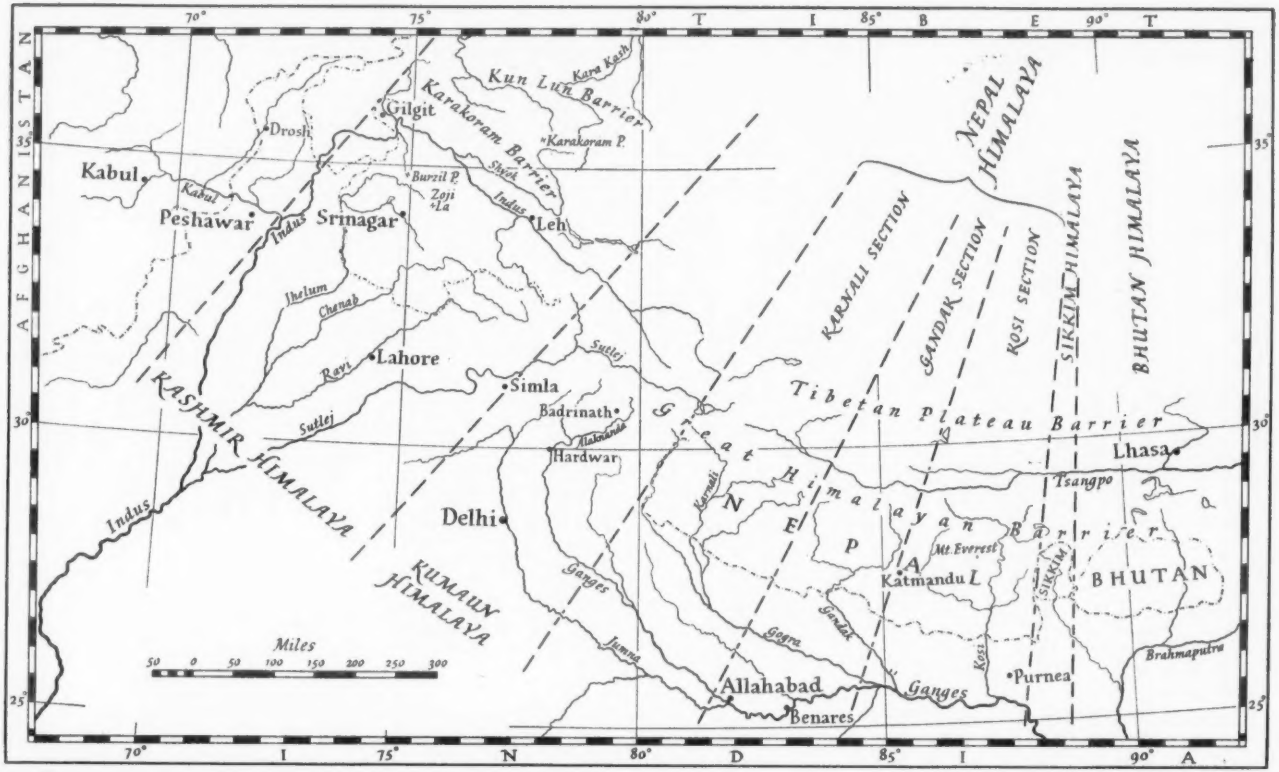
The most important railway connection that has been completed, the Turk–Sib line, links the Tashkent–Orenburg railway some miles north of Tashkent with the Trans-Siberian. It leaves the former at Aris, passes north of the Tien Shan and Issiq Köl to Alma Ata, not far from the Sinkiang frontier, and then northwards to the east of Lake Balkhash through Semipalatinsk to Novo Sibirsk. Certain small branches feel their way towards the Sinkiang frontier. The Trans-Siberian line has been double-tracked almost throughout its length, and other connections between the Trans-Siberian and Turk–Sib lines are under construction. To what extent these developments have been dictated by strategic motives, and how much has been due to economic requirements, it is not for me to say.

Now if we examine a map showing the important railways of Europe and Asia as they exist to-day, we notice the following points:

(1) India is supplied with a dense network of economic railways.

(2) Russia has three main lines stretching outwards to Central Asia, while behind her frontier with Persia, Afghanistan, Sinkiang, and Mongolia, she has a long line connecting the three main lines.

(3) For the rest, as far as Asia is concerned, railway development takes the form of rather insignificant pushings in from the coast. There is the Baghdad railway, still with a break between Nisibin and a point south of Mosul, with a difference of gauge in the two completed sections. The Persian line, under construction from both ends between the Caspian and the Persian Gulf, is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Sutlej
Simla
Badrinath
Alaknanda
Hardwar
Ganges
Jumna
Delhi
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KUMAUN HIMALAYA
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Katmandu
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Brahmaputra
Purnea
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Allahabad
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still a long way from completion. The Indian system, extended to the extreme west of Baluchistan during the war, to Duzdab, has not only moved no farther on, but the last section of 200 miles between Duzdab and Nokkundi was abandoned in 1932 as uneconomic. Meanwhile the road made fit for motors to serve the communications of General Malleson's force at Meshed has fallen out of repair. In eastern India the railway link between Assam and northern Burma has got no farther than the survey stage.

Nor has the unsettled state of China permitted the Nanking government to undertake much development, and except for activity in Manchukuo, there is nothing else to record. No important lines have been constructed south of the Great Wall. India has indeed constructed a railway through the Khyber, but otherwise she is as isolated as ever she was from the Russian and Chinese frontiers, for Afghanistan, Sinkiang, Tibet, and Mongolia, are still untouched by railways.

Since the war however many of our old ideas regarding isolation have undergone modification owing to the development of motor and air transport. Seas and deserts, in particular, have almost ceased to exist as barriers to movement, while several of the larger mountain ranges of the earth are crossed regularly by scheduled air-liners. The Rockies, the Andes, the Atlas, and the Alps, are all crossed by mail planes, while the Syrian desert and the Sahara are regularly traversed by motors and by aircraft. In many parts of Africa motor-road development is largely superseding railway construction, for with suitable restrictions during the rainy season such roads are much less costly to maintain.

In Asia also there has been development. A regular air service exists from Moscow to Irkutsk near the south-west end of Lake Baikal, taking the course of the Trans-Siberian railway, and but for political considerations, would be doubtless extended to China. Indeed, it is possible, with permission, to charter a plane and travel from Irkutsk to Manchuria and Peiping, and even from Sergiopol across Sinkiang, by Urumchi and Hami, to Lanchow, the terminus of a fairly regular service in China. From various points of this trans-continental air-line, it is also possible now to fly to distant points in the north; but at present there is insufficient traffic for regular services.

India, too, is becoming air-minded. I look back with mixed feelings to twenty-five years ago, when in December 1910 the first plane seen east of Suez arrived at Allahabad and began what were optimistically called "joy-flights." The machine was a Sommer biplane, of the pusher type, with rotary gnome engine. The receipt for payment of my flight was numbered "4," which means, I think, that I was the fifth person to fly in India. The machine had no fuselage, and before climbing on to what was called the pilot's seat on the bottom plane, my friends shook me warmly by the hand and said "good-bye." Pequet, the pilot, tucked himself between my knees, and we managed to get up to about 500 feet. This plane carried the first authorized air-mails in India, and I believe, in the world, in January 1911. Letters posted on the aerodrome were handed to the pilot, who flew them to a small special post-office, where they were taken over by the normal service.

Since the war India has of course become linked by air with Great Britain and Western Europe, and there are now three lines which control the regular

services across India: Indian Trans-Continental Airways, a subsidiary of Imperial Airways, and the French and Dutch lines, Air France and K.L.M.

I.T.C.A. runs two services a week in each direction between Karachi and Singapore: Karachi, Jodhpur, Delhi, Cawnpore, Allahabad, Calcutta, Akyab, Rangoon, Bangkok, Alorstar, Singapore. An Australian line connects Port Darwin with one of these bi-weekly services at Singapore, and Port Darwin is connected with various parts of the Australian Commonwealth. In his very interesting report last week on the development of Imperial Airways, Sir Eric Geddes stated that the Singapore–Port Darwin service would shortly be doubled, and that with the aircraft now under construction India would be reached in three days, and Australia in seven.

Air France runs one service a week in each direction between Paris and Saigon, and K.L.M. two services a week in each direction between Amsterdam and Batavia. Both these lines fly direct from Jodhpur to Allahabad, but otherwise take the same route as I.T.C.A. across India.

There are two regular feeder services running in connection with I.T.C.A.: (1) Karachi, Sukkur, Multan, Lahore, twice a week in each direction, operated by Indian National Airways; and (2) Karachi, Ahmedabad, Bombay, Hyderabad, Madras, twice weekly by Tata, Ltd. This is shortly being extended from Madras to Colombo. Both feeder services are operated with small single-engined aircraft and are run principally for mails; they only occasionally carry passengers.

That, I understand, is the position as it is to-day, or as it was at any rate a month ago. A firm called the Himalayan Air Transport and Survey, Ltd., has been carrying pilgrims from Hardwar to Badrinath, well in the hills on the Alaknanda tributary of the Ganges, and there is some talk of making this a scheduled service at certain periods of the year. Indian National Airways have also submitted proposals for a service between Lahore and Srinagar in Kashmir. Experimental flights have been carried out, and I learn from India that Srinagar's new aerodrome was opened on September 2. According to my information, the plane that flew the journey on that occasion left Delhi at 6 a.m., stopped for half an hour at Lahore, and reached Srinagar at 11.20 a.m.

These two embryo services are not of course the first occasions when planes have flown over or into the Himalaya. As long ago as 1925 I can remember R.A.F. planes flying over the Ridge at Simla during the King's Birthday parade, and they may have done so earlier. On 28 March 1929 a flight of four R.A.F. Wapiti aeroplanes flew from Risalpur, by Chakdara and the gorge of the Indus to Gilgit, and since that date the R.A.F. have, I believe, carried out the Gilgit flight with service planes regularly once a year. Along the Indus gorge the planes travel at about 12,000 feet, that is about 10,000 feet above the valley bottom, while the mountains rise in places on either hand in stupendous precipices of 15,000 feet. In 1932 a flight of five Hart machines completed the journey of 286 miles in two hours twenty minutes, passing close to Nanga Parbat.

In India also there are private flying clubs and a very enterprising Air Survey Company. Flights for police and other purposes have become a regular routine on the N.W. Frontier, while most of you will recollect the very fine performance of the Royal Air Force in evacuating the staffs of the various

R.A.F. planes passing Nanga Parbat, 17 Oct. 1932

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Over the Indus

Over the Indus

legations at Kabul during the insurrection against King Amanullah in 1929. It is extraordinary how quickly the inhabitants get used to aeroplanes. In 1929 the Mirs and chiefs of the Gilgit Agency were uncertain whether it was great daring or gross sacrilege to approach an aeroplane upon the ground. In 1933 the enterprising Mehtar of Chitral flew over the North-West Frontier hills to his new aerodrome at Drosh. The only other flight that need be mentioned at this stage is the spectacular Mount Everest Flight in the same year.

On the far side of the Iranian plateau, beyond the Hindu Kush, there is, I understand, no regular scheduled air service between Moscow and the Soviet Republics of Turkistan; but there are no physical obstructions to flying, there are landing facilities at most of the large towns, and Soviet officials use the air a good deal in the course of their duties. Nevertheless, no one has yet flown overland to India from Soviet Asia over the mountain barrier. Kabul has been reached by air from beyond the Soviet and the Indian frontiers; but no one has completed the through journey, and no one has yet thought it worth while to attempt any other route.

If we examine the state of motor-road development, we find much the same state of affairs. On both sides of the mountain barrier good roads have been constructed. In a few instances surveys have been made for extensions of such roads farther into the hills; but no one has yet succeeded in getting wheeled traffic across the whole barrier. In this connection you may remember the effort made by the Haardt Expedition in 1931–32. Of the seven light six-wheeled caterpillar-tractors which left Beirut, and which reached India by way of Herat, Kandahar, Kabul, and the Khyber, two only succeeded in reaching Gilgit, and one of these managed to get a few miles farther. I use the words "succeeded" and "managed" advisedly, for the journey took considerably longer than it would have taken to crawl the whole distance on all fours, the cars had to be winched and jacked round many of the bends, and at one point they had to be entirely dismantled and carried across a bad stretch of the track on the backs of coolies. An officer who met the expedition on the Gilgit road told me that one of the party walked backwards in front of the cars to insure that they did not go over the precipice into the Astor river below.

This examination of the present position leads me to observe that a map of Asia showing air routes for scheduled and unscheduled flights, roads fit for motors, and existing railways, is no certain guide to what may be possible in the future. The extension of air-routes throughout the world has been mainly due to private enterprise and individual daring. But such enterprise can only be fully effective if all countries are sympathetic to intercourse by air. When therefore we see on such a map the lack of modern communications across the northern frontiers of India, we have to take into consideration the political factor as well as the physical barrier.

Let us consider the political factor. Flying over the states bordering India is prohibited by the governments of those states, and we respect their wishes. Afghanistan has a small air force of her own which flies within her frontiers, but on this sector of the Indian borderland no one is permitted to fly from one side of the boundary to the other. Tibet, Nepal, and Bhutan have no aircraft and want none; their rulers are definitely averse to Europeans entering their countries at all. Permission to fly over them in existing circumstances is

almost impossible to obtain, and has only been given once by Nepal and never by the other two.

China is, as we should say in the West, more "progressive." Assuming, then, that China and her loosely controlled province of Sinkiang might possibly be willing to permit flying over the latter country, the only routes across the Himalayan frontiers of India must lie between the North-West Frontier hills and the western boundary of Nepal. The whole of the rest of the Himalayan frontier is enclosed by Tibet on the north. This sector west of Nepal contains the state of Kashmir, whose Maharaja is sufficiently air-minded to fly out to India by Imperial Airways, and thence by private plane to Srinagar.

So much for the political considerations. Before considering in detail the best lines for air travel across the Himalaya, irrespective of those considerations, I will draw attention to certain governing factors of air travel. And here, being no expert, I must be subject to correction. I am told that, though it is possible to land with a light load at 15,000 feet, it is much more dangerous, if not impossible, to take off above that altitude. Aeroplanes presumably could be designed for the special purpose of high altitude landing and taking off, but such planes, I understand, would not be so handy at lower levels. Flying over mountainous country for long stretches is very much more difficult than over lower and more populous levels. An air-route over mountains covered in snow or clothed in forest is difficult to identify from the air, and the lack of obvious landmarks makes it difficult to keep to a definite course; engines develop trouble more easily at high altitudes; storms and cloud, with consequent bad visibility, are more frequent; and forced landings may be most common where the ground is least suitable. In mountainous country wind currents are more variable, while, if one attempts to avoid them by flying at great altitudes, additional oxygen and special warming apparatus for man, machine, engine, fuel, and instruments are necessary, and add considerably to the cost.

Neglecting political considerations, let us now consider the shortest routes by air between London and India. Bombay is roughly half-way on a great circle course between London and Perth in Australia. There may come a day when it will be possible to fly that course in twenty-four hours, stopping for lunch at the Gateway of India. But the day is not yet. The great circle course between London and Bombay would approximately take the line London, Cologne, Sebastopol, Batum, Tehran, Seistan, Karachi. That course itself would shorten the journey to Karachi by more than a day even at present cruising speeds. The great circle course between London and Calcutta would be farther north: London, Berlin, Warsaw, Kiev, Astrakhan, and a little north of Bukhara, the Khyber, Delhi, Allahabad. Its continuation would be to Rangoon and Bangkok. It will be observed that neither of these two great circle courses passes over the high Himalaya. Nor would a great circle course from Tokyo to Calcutta pass over them. Nanking and Hankow would be on such a route and it would enter India a little south of the Lohit branch of the Brahmaputra. It seems to me that for long distance air-routes such as these, multiple-engined air-liners of special construction could be designed to make the journey without excessive risk, always provided the

political considerations were favourable. Judging by what has already been accomplished, the routes Batum, Tehran, Duzdab, Karachi, and Astrakhan, Bukhara, Termez, Kabul, Peshawar, are quite practicable.

With the Himalaya however the problem is different. The distances over the mountains are considerably greater, the altitudes much higher, the country much more rugged, and beyond the Himalaya there is either the additional broken country of the Karakoram, or the wide 16,000-foot plateau of Tibet. Even these are not the end of difficulties. The Kun-Lun forms a further obstacle, while either the Pamirs or the uninhabited Taklamakan desert, as well as the Tien Shan have still to be crossed before the main artery of Asiatic communication is reached. The shortest distance between the existing trans-Indian and trans-Siberian air-routes is about 1800 miles of this difficult country, though the Turk-Sib line at Alma Ata, the railway centre near Lake Issiq Köl and the Sinkiang frontier, is only about 1000 miles from Lahore. It may be that, with the gradual shifting of the economic centre of the U.S.S.R. to the region of Omsk in Asia, some such long distance connection will become advisable. When I look back to the developments of the last twenty-five years I cannot help feeling that it will certainly become possible.

But perhaps I should confine myself to what would be practicable at present, if it were not for political considerations, and I propose now to examine the barrier by itself in some detail. I need hardly remind you that the existing method of transport is by pony, yak, sheep, or man, and that very few of the land routes are open for more than six months of the year. There are high snowbound passes and profound gorges to be traversed. Some of the less important routes are full of difficulties, the rivers being unbridged or only crossed by rope suspension bridges. In the densely forested east the track may be taken along the hillside on bamboo platforms. In the drier regions of the west the track may climb over the barren precipices 1000 feet above the rivers. Travelling off the main trade-routes is still primitive, and I for one hope that it will long remain so.

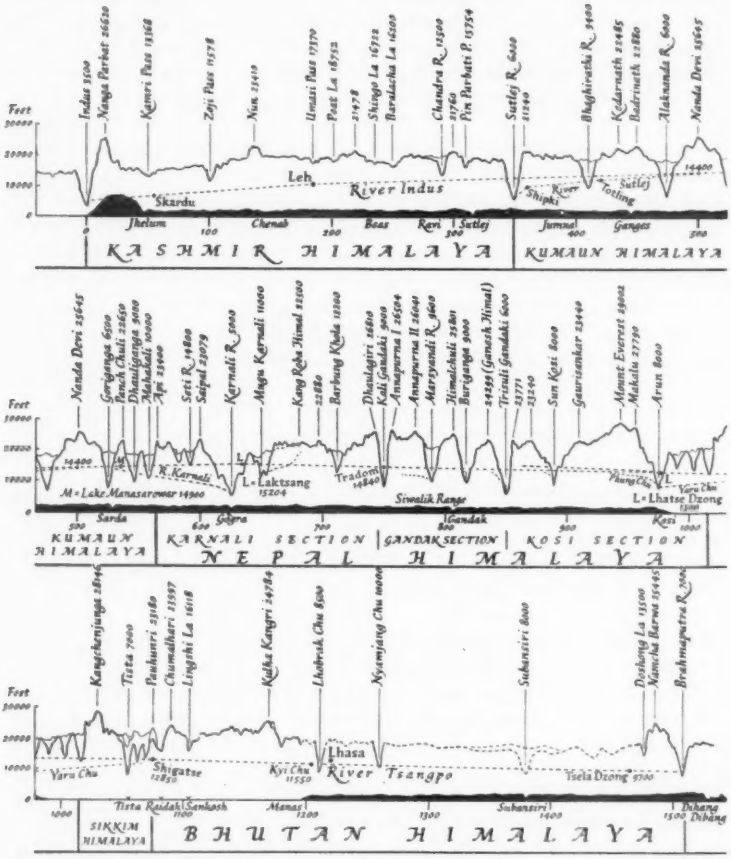
It is usual for geographers to divide the Himalaya into three zones: the outer Himalaya, comprising the low Siwaliks and the *Duns* behind them; the Lesser Himalaya, made up of the eroded ranges and ridges north of the Siwaliks; and the Great Himalayan zone which contains the great peaks. The distance in a direct line from Lahore to Kashgar is about 600 miles, and from Calcutta to Lhasa not much less.

At a few points the Siwalik zone is entered and crossed by railways, as, for instance, at Hardwar, where the Ganges breaks through the range; and at two points, Simla and Darjeeling, the railway climbs laboriously up to the outer edge of the Lesser Himalaya. The outer zone is crossed at many places by modern motor roads, and it cannot be said to present obstacles to aircraft.

The general altitude of the hills of the Lesser Himalaya varies from 7000 feet to 15,000 and even 16,000 feet. Within it there are certain open valleys, which are considerably lower. The Vale of Kashmir, north of the 15,000-foot Pir Panjal, is at 5000 feet; Katmandu, in the valley of Nepal, is at 4200 feet. As I have already stated, aircraft have already landed at Srinagar and at Badrinath in the Alaknanda valley, in the Lesser Himalayan zone. This zone is undoubtedly practicable for aircraft by certain routes, and at certain seasons

of the year; though landing-grounds would have to be prepared with more than ordinary care, and emergency landings, except in a few open valleys, would always be dangerous.

As regards motor roads, there are two good routes to the Vale of Kashmir, and motors can reach most of the Himalayan hill-stations. Some of these



Longitudinal section of the Great Himalaya from the Indus to the Brahmaputra. Horizontal scale in miles measured approximately from the Indus

roads have been extended farther into the hills, as for instance to Kulu, where there is some economic justification. They are however constantly liable to interruption by landslips and are costly to maintain. Undoubtedly roads, such as the Treaty High Road, between Srinagar and Leh by the Zoji La, or the Hindustan–Tibet Road through Bashahr, could be made fit for motors and kept open for some months of the year; but it is difficult to see how they

could be economically justified in view of the small amount of trade, and the heavy snowfall during the winter months.

Nevertheless it is the Great Himalayan zone that presents the most formidable obstacle. This forms a great barrier averaging 40 or 50 miles wide, with a double and sometimes a treble crest zone of peaks. Except in Kashmir, where the average elevation of the range is about 17,000 feet, the average altitude is roughly at 20,000 feet, with many great massifs rising to 23,000 and even 25,000 feet. A longitudinal section of the range shows that where it has a high average crest altitude and many higher mountain groups, it has been cut into blocks by deep gorges, while towards the extremities, in Kashmir, and probably in Bhutan, where the general altitude is lower, the carving of the great range is less marked. It is in fact a very noticeable fact that the highest mountains are closely associated with the deepest gorges, especially in Nepal. In Eastern Nepal, Sikkim, and Western Bhutan, the outer Himalaya have been entirely eroded away, the Lesser Himalaya have been very largely destroyed as ranges, and the watershed of the Great Himalaya has been driven back into the Tibetan plateau.

These points are, I think, obvious from the section that I have drawn from large-scale maps. I have shown the mountain blocks and the river gorges to scale. In general, it is by these breaks in the main range that the limited communication between India and Tibet, or Nepal and Tibet, takes place. In Kashmir, where there are no such gorges between the Indus and the Sutlej, caravans make use of passes over low depressions in the range.

The most important routes from west to east cross the Great Himalaya at the following gaps:

From	*To*	*At*	*Height*
Srinagar	Gilgit	Kamri pass	13,368
		or Burzil pass	13,775
Srinagar	Leh	Zoji La	11,578
Simla or Kulu	Leh	Baralacha La	16,200
Simla	Shipki	Sutlej valley (H.T. road)	*c.* 6,000
Tehri	Totling	Bhagirathi valley	*c.* 9,400
Garhwal	Totling	Alaknanda valley	*c.* 6,000
Almora	Gyanima	Goriganga valley	*c.* 6,500
W. Nepal	Laktsang	Karnali valley	*c.* 5,000
Central Nepal	Tradom	Kali Gandaki valley	*c.* 9,000
E. Nepal	Lhatse and Lhasa	Sun Kosi valley	*c.* 8,000
E. Nepal	Lhatse and Lhasa	Arun valley	*c.* 8,000
Sikkim	Shigatse and Lhasa	Tista valley	*c.* 7,000

I do not mean to infer that these are the highest points reached by these routes, but merely the altitudes at which the Great Himalayan axis is crossed.

Considering the very high altitudes that aircraft would have to fly to clear the range itself, it is interesting to examine the possibility of using these valley routes. Valley routes have certain advantages as well as disadvantages for air travel. Among their advantages I would put the comparative ease of identifying the route; the lower altitude of the flight; the finer weather, owing to local rain-shadowing; the greater likelihood of suitable ground for forced

landings. The disadvantages seem to be the danger from air pockets and shifting winds, and the consequent danger of hitting the mountain side if visibility is bad. Applying the advantages and disadvantages to the different valley routes enumerated, I would put the Sutlej and the Karnali as the most suitable routes for air travel, then the Alaknanda, the Arun, the Tista, and possibly the Sun Kosi, while I would rule out the Bhagirathi, the Goriganga, and particularly the Kali Gandaki, as dangerous. In Kashmir there seem to be no great objections to the Kamri, the Burzil, or the Zoji La. Unfortunately, in the Kashmir section, where the Himalaya is lower, the real obstacle comes from the ruggedness and altitude of the Karakoram range north of it. From Gilgit the Karakoram can be turned by the course of the Hunza valley; from Leh, less easily by the upper Shyok and the Depsang plains. It is just possible that a forced landing here might not be fatal, though it would have to be made at a high speed; but it would be much too high with existing designs of aircraft for a successful take-off again. The main mass of the Karakoram should most certainly be avoided.

In view of what I have already said regarding rail and motor possibilities in the Lesser Himalayan zone, it would be superfluous to discuss such development across the Great Himalayan zone in detail. But there is one point which is important. Roads fit for motors could be constructed across the plateaux of Tibet and the Pamirs to the northern foot of the Himalaya or Karakoram without any great difficulty. It is the actual gorges through the range and the weather-worn southern flanks which form the most formidable barrier to motor traffic. Such roads across the high plateaux would however never be economically justified.

I have left the question of weather to the end. The Himalaya forms an almost impassable barrier to the south-west monsoon. Beyond it we get the clear atmosphere of Tibet. I believe that no one in their senses would attempt to cross the Lesser Himalaya by air during the monsoon period from say June 20 until mid-September, except perhaps in a multiple-engined air-liner with a ceiling of 40,000 feet, with everything and every one artificially warmed. The monsoon is a low-altitude current and the clouds break against the mountain sides. In the eastern Himalaya the monsoon is particularly heavy and prolonged. At Darjeeling, for instance, the average rainfall for the four months from June to September, taken over a period of thirty-eight years, is 102 inches. Eighty-eight days in these four months are wet, and visibility is generally bad on the remaining days. The highest summits might be clear, but they would be like islands in an ocean of cloud. I need not stress the dangers of attempting to cross such a country at such a time.

The other period of unsettled weather is due to "western disturbances," beginning towards the end of December and lasting in the high Himalaya of Kashmir as late as the beginning of May. It is these disturbances that recover the Himalaya with snow. In March and April it is usual to have spells of five fine days between spells of bad weather. The intervening periods, from early May to June 20, and from the end of September to mid-December, are generally fine and present good flying weather. November is the finest month throughout the Himalaya. Visibility is then about as perfect as any pilot could wish for. There are more wet and cloudy days in the period May–

June, before the monsoon breaks than after it is over, but when fine, visibility is good and the temperature is less exacting than in November. The outer ranges, such as the Pir Panjal, of course, do rain-shadow the valleys to the north to some extent, and the published figures for stations in the Vale of Kashmir seem to indicate that the monsoon is largely ineffective here. This is however not so; for while the amount of rainfall is effectively diminished by the outer ranges, the actual number of wet and cloudy days is still considerable even in the valleys, while the surrounding hills are much worse off than the lower stations. I remember years ago, on the false assumption that the greater part of the monsoon rainfall was precipitated on the outer hills, and that the inner hills could be relied upon for generally fine weather, we attempted to carry on our survey throughout the monsoon period. It turned out that not one day in six was fit for work. Beyond the Great Himalaya it is a different matter altogether, but the airman has to get there first.

I could enlarge further on the physical obstacles to communications across the Himalaya and describe the difficulties due to forest growth, landslides, avalanches, and the rest of Nature's mountain armaments. But I have said enough. Whatever the future brings in the way of surprise, it seems to me that the Himalaya will always remain the pedestrian's paradise. Motor roads and railways have been developed as far as they are economically justified; we want no more of them. Political and physical obstacles combine with technical difficulties to prevent air development across this barrier; I thank God for that! And until we can cross it in artificially warmed, multiple-engined air-liners, with a ceiling of 40,000 feet, in one "hop" of 1000 miles or so, I see no prospect of air development. And I am glad that it should be so.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: The lecture to-night is the Sixth Asia Lecture. The last was delivered in March 1934 by a missionary lady, Miss Mildred Cable, on her experiences in Dzungaria. To-night Professor Mason is to lecture to us on "The Himalaya as a Barrier to Modern Communications."

The Asia Lecture, I would remind you, was endowed by the Rev. Livingstone Dickson to provide a lecture every second year on some subject of general interest appertaining to Asia: and we are very glad to have Mr. Dickson with us to-night.

Professor Mason needs little introduction to any one in this audience. He was for many years in the Survey of India. He has a thorough knowledge of the Himalaya from all points of view: as a climber, explorer, and surveyor. You could hardly have a better combination for speaking with authority on any subject connected with the Himalaya.

As to the question of a barrier to communication, I first went to India half a century ago, and I remember that in those days we regarded the Himalaya as an absolute barrier to the possibility of a Russian advance towards India. We shall hear from Professor Mason how he regards that aspect of the Himalaya under modern conditions. They have changed greatly.

Professor Mason then delivered the lecture printed above, and a discussion followed.

The PRESIDENT: Sir Francis Younghusband is here, and to us he is the father of the Himalaya. I remember fifty years ago, nearly, when he came across from

China, what a stir it created among his young comrades in India. I will ask him to speak.

Sir FRANCIS YOUNGHUSBAND: As I listened to the lecturer it struck me that he was talking against the grain the whole way through. He was talking about flying across the Himalaya when all the time he was longing to be walking across it. It was only in the very last sentence, when he said that the Himalaya was the pedestrian's paradise that his true heart came out. Very fortunately for me I was a pedestrian, and am now, and crossed the Himalaya eleven times from the plains of India to the plains of Turkistan, or the Pamirs, or to Tibet, and back, and I should agree with the main conclusion of Professor Mason, that while that barrier is fairly easy of access from the north it is always on the south that you get the real difficulties, either having to cross high passes or go through the most tremendous gorges. I should imagine the best way in the future would probably lie through the Hunza valley. Terrific gorges would be met with, but they can be negotiated, and it is the nearest way to Central Asia. By the Karakoram is a long way round, and you have to cross some very high passes.

I know nothing at all about flying, but I was wondering, as I listened to the lecture, whether those new machines, the autogyros, would be in future, perhaps, of more use than ordinary planes when flying up those valleys.

Then there is a little detail—I do not know whether it is worth mentioning. The lecturer spoke about the rivers cutting through the Himalaya. It is very noticeable that some of the greatest rivers rise on the northern side of the Himalaya—the Brahmaputra and the Indus, the Sutlej and the Arun—and find their way through the barrier, and it may be that the river is older than the mountains. It may not be that the river started first and cut its way through the mountains, but that the mountains have gradually risen on each side of the river.

As regards the economic worth of any route through these mountains to Turkistan or Tibet I would imagine there was very little to be gained. As the lecturer has said, there could never be very much trade between the plains of Turkistan and the plains of India. So I would agree with him in what he said as regards the economic worth of any routes that way.

I conclude by congratulating Professor Mason upon having recovered his real heart at the end of his lecture. I hope he will always keep it.

The PRESIDENT: We have Mr. Ruttledge with us, whom we hope is going to the Himalaya. Perhaps he will come and say a word or two.

Mr. HUGH RUTTLEDGE: It is a great privilege for an ordinary pedestrian to be allowed to follow that most distinguished pedestrian, Sir Francis Younghusband, in congratulating his old school-fellow and fellow-pedestrian, Professor Mason.

I think it is pretty clear from Professor Mason's lecture that the crossing of that great barrier is very difficult in nearly all places except the old, traditional route up by the North-West Frontier. The parts that I know slightly are the Central Kumaun Himalaya and the eastern end. Personally, I should be very sorry indeed to try to fly up through those gorges of the Kumaun Himalaya. I daresay Professor Mason would not mind because I saw him go up on those early flights at Allahabad and I know he risked his life during the few moments he was up. The wind, what is called locally "Ṛáni ka punkha," in the Kumaun gorges is simply terrific. I do not think you would have the slightest chance if anything went wrong with your plane. I daresay you could get up at the eastern end, by the Chumbi Valley, but it does not seem to be worth it. The only places that will be worth coming down through, I think, will be on the west, but I naturally hope the day will be far distant when the combustion engine replaces

the homely yak and those gallant, simple people of the hills with whom it is such a privilege to associate.

The PRESIDENT: Sir Percy Sykes, would you be so good as to speak to us for a few minutes?

Sir PERCY SYKES: Professor Mason has looked at the Himalayas more or less from India. I have looked at them on the other side, on the north, from Kashgar and Yarkand. When I was there some twenty years ago I do not think we had ever heard of aeroplanes in the country, but goods were sent by pony caravans over the Himalayas to Ludakh and India. The big range across which lay the route was called the Karakoram. It was known among us as the "Ridgepole of the World." The range was only open for about five or six months in the year, and a variety of goods were carried across it: a certain amount of jade, a certain amount of hemp, and a certain amount of silk. In return the traders brought back Manchester goods, and sugar, tea, and so forth. On the whole, the natives bravely faced the difficulties of the route and were certainly practical. For instance, it is very cold in that part of the world, and they always very kindly gave the sheep overcoats when they marched them, and in order to make the coats quite warm they filled them up with borax, which is one of the exports; so they really are very practical people.

As to flying, of which we have heard a great deal, there is one thing which Professor Mason has not told us, namely, that in Chinese Turkistan, where I do not think he has been, the loess in the atmosphere makes it absolutely impossible to see more than 200 or 300 yards, which rather knocks a multiple-engined aeroplane, or any other type. I once travelled through Kashgar, Yarkand, and then to Khotan, where there is a huge range, the Kun-Lun. I noticed in reading Marco Polo that he never mentioned the existence of that range. I went along it to Khotan and I never saw it either, the reason being that the loess rendered the whole range invisible, and that is the case practically all the year through. This fact, I think, is rather against flying in that part of the world.

I may add that when my sister and I mounted the Pamirs, the "Roof of the World," I had the pleasure of meeting the Russian Survey Officers, who had completed the triangulation with the British, and I must say they had the greatest admiration for our lecturer and the very fine achievement by British officers of that very difficult piece of work.

Finally, may I say a word about Persia, namely about the railway there? The railway is not quite as Professor Mason said. It has been started from Khor Musa, an inlet situated at the top of the Persian Gulf into the interior from that end, and it is also making very good progress from the north through the main Elburz range. It is expected that it will be finished in about four or five years' time.

We have heard an extraordinarily valuable lecture and, as it deals with a part of the world in which I have spent most of my life, it has been of special interest to me.

The PRESIDENT: I do not know whether there is any Air Force officer here who would care to comment on the air aspects of the problem? Apparently not.

It only remains for me to sum up. I am sure that you will agree with me that we have had a most instructive and a most efficient lecture. I do not think the problem could have been more lucidly stated nor any illustrations more apt than those shown by Professor Mason.

Not being an airman, I know little about air possibilities, but it seems to me that pending the invention of an autogyro or helicopter it would be quite impossible to negotiate the Himalaya for any commercial purpose by aeroplane.

I will not detain you further. I only ask you to join me in thanking Professor

Mason for his very fine lecture. He must have spent an infinity of time and trouble to prepare such an efficient and satisfactory discourse. I ask you to join me in thanking him most warmly.

Editor's Note.—During the course of the discussion the point of the correct pronunciation of the word "Himalaya" was raised. This has already been discussed in the *Journal* (vol. 84, p. 395), and it has therefore been considered unnecessary to include the discussion here. No new facts were produced and no conclusion reached.

PHYSIOGRAPHIC HISTORY OF THE YANGTZE[1]: *A paper read at the Afternoon Meeting of the Society on 11 November 1935, by*

GEORGE B. BARBOUR

OF the challenging problems presented by the Great River of China none is more intriguing than that of its origin and development. There is no lack of descriptive writing dealing with the Yangtze, much of it superficial and of little scientific value. Hitherto references to its evolution as a trunk river have been less frequent, largely owing to lack of data to support sound hypotheses.[2] Only recently have physiographic and structural observations been made in sufficient detail to let us interpret the river's history with any confidence.

Captains of steam craft divide the Yangtze into three sections on the basis of the depth available at low water for boats of shallow draft. The Maritime Customs stations at Ichang and Hankow mark the points at which the navigable river is thus separated into Upper, Middle, and Lower Divisions. A glance at the block-diagram however shows that no fundamental change in stream character occurs at the Hankow confluence (see Plate I), the increased depth below that point being due almost entirely to contributions from the Han, Hsiang and Yuan basins. In fact the true Lower Yangtze begins at Ichang, and is a physiographic unity from there to the delta (see Fig. 1). As here used therefore the term Lower Yangtze includes both the lower and middle divisions of the pilots.

The true Middle Yangtze extends from the entrance of the Ichang gorges up to Pingshan. The justification for separating this stretch from the upper reaches is perhaps not so obvious, because though junks can ply only a few miles above this limit—Hosie came down by boat from Man-i-ssu, 12 miles farther up-stream[3]—elevations recorded by Baber[4] and others show that there is no abrupt change of gradient at Pingshan like that at Ichang. Nevertheless the contrast between the course above and below the upper entrance

[1] This paper, published by courtesy of the Director of the Cenozoic Laboratory, Geological Survey of China, outlines the results of an expedition made in 1934 by the writer, as Visiting Physiographer to the laboratory, in company with P. Teilhard de Chardin and Dr. C. C. Young. The study was planned by the late Dr. Davidson Black as one of a series of coordinated research projects arising out of the discovery of the Peking Man.

[2] Until the appearance of v. Richthofen's authoritative work ('China,' vol. 1, Berlin, 1877, pp. 645 ff.) and Yule's scholarly introduction to Captain Gill's 'River of Golden Sand,' the best survey of existing knowledge apart from Chinese sources was probably to be found in Ritter's 'Asien' (1837). Carles's study published in this *Journal* (W. R. Carles, *Geogr. J.*, vol. 12, 1898, pp. 225–40) gives a well-documented account of the progress of exploration down to the end of last century. Later writings of Bouterwek (K. Bouterwek, "Das Land der meridionalen Stromfurchen," *Mitt. geog. Gesell. München*, vol. 13, 1919, pp. 161–341) and Gregory (J. W. Gregory "Geology and Physical Geography of Chinese Tibet," *Phil. Trans.*, Ser. B, vol. 213, 1925, pp. 172–298) for the Upper Yangtze, and regional studies by J. S. Lee, C. Y. Hsieh, and other authors for the middle and lower basins bring the record up to date.

[3] Alexander Hosie, 'Three Years in Western China,' 1880, London, p. 184.

[4] E. C. Baber, "Travels and Researches in Western China," *Roy. Geogr. Soc. supp. papers*, vol. 1, 1886, pp. 146, 188. See also Hardy, "Some Upper Yangtze River Elevations," *Jour. W. China Bord. Res. Soc.*, vol. 2, 1925.

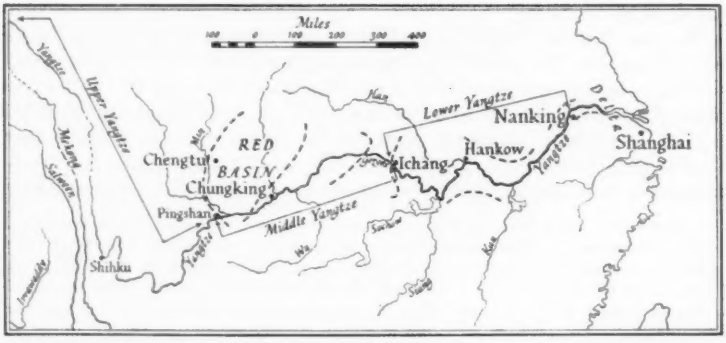
to the Red Basin corresponds to a difference in history of the two sections which is reflected in the fall of the river as a whole. Pingshan lies 1630 miles from the sea at an altitude of 800 feet. If the total length of the Yangtze below its gathering ground at 17,000 feet elevation is taken as 3200 miles, the river falls 16,200 feet in the first 1570 miles of its course. In round numbers, this means a drop of 16,000 feet in the first 1600 miles and one of only 800 feet in the second 1600 miles.

The precise up-stream limit of the delta is a matter of arbitrary agreement. Nautically, it is desirable to include the entire Nanking reach of the Yangtze within the scope of the Whangpoo Conservancy, and this surveillance therefore extends up to Wuhu. Physiographically the dividing line may conveniently be placed at Nanking, 50 miles nearer the mouth, where the flood-plain widens below the last constricting node of bed-rock.

The river's development may therefore be considered in the following sections:

Upper Yangtze	.. ..	Headwaters to Pingshan
Middle Yangtze	.. ..	Pingshan to Ichang
Lower Yangtze	.. ..	Ichang to Nanking
Yangtze Delta	.. ..	Nanking to the sea.

The most striking contrast between these sections lies in the way the river responds to the control of the bed-rock structures. Referring again to the


Miles
100 0 100 200 300 400
Yangtze
Upper Yangtze
Mekong
Salween
Irrawaddy
RED
BASIN
Chengtu
Chungking
Pingshan
Shihku
Middle Yangtze
Han
Lower Yangtze
Nanking
Hankow
Ichang
Shanghai
Yangtze
Yangtze
Yangtze

athwart the grain of the structure at many points. In entrenching itself in its gorges, the Yangtze flouts the control which a strongly developed fold-system might have been expected to exert on its direction of flow.

On the upper river, two sharply contrasting patterns are seen in the drainage (Fig. 1): (*a*) the long straight meridional stretch where for over 400 miles it parallels the Mekong and Salween, and (*b*) the zigzag course below the Shihku bend from which it works its tortuous way east to the Red Basin.

The structures of the bed-rock foundation do not all date from the same epoch. But as far as the Yangtze is concerned the first major control was established towards the close of the Mesozoic Era, when the entire region was fundamentally affected by the vigorous Yenshan mountain-folding movement. Tertiary disturbances were less widespread in effect and were most marked in what became the alpine region along the Tibetan front.

Upper Yangtze

"The course of the Kiang begins on the Minshan." This sentence from the Yukung, ascribed by tradition to Confucius, leaves no doubt as to the views of early Chinese geographers regarding the source of the Yangtze. The Kinsha-kiang, or Upper Yangtze, was thought of as only a tributary to the Min-kiang which, rising in north-west Szechwan, flows past Chiating to its junction with the Yangtze at Suifu. The same conception is embodied in Padre Martini's Atlas (1664) [1] and it is reiterated in an edict of the Emperor Kang-Hsi (1721) in which the Ta-kiang, or Great River, is listed separately from the Kinsha-kiang among the great rivers of the empire.

Unwittingly the misconception comes in a sense nearer the truth regarding the ancestral lineage of the river than our maps of to-day suggest. For the Min-kiang, or one of its major tributaries, is possibly more truly the parent of the Middle and Lower Yangtze system than the Kinsha-kiang itself. The Ming dynasty explorer Hsu Hsia-k'o (1586–1641), the first to sense the earlier relationship between the present river and some of its tributaries, drew attention [2] to the significance of the wind-gap south of the Shihku bend of the Yangtze, and among the Moso tribes tradition holds that the upper waters of the river once emptied south into the Mekong through the Yangpi depression [3] (see Fig. 2).

Ten years before the late Professor J. W. Gregory made his expedition to south-west China, he was discussing Davies' map of Yunnan with Dr. V. K. Ting (subsequently Director of the Chinese Geological Survey), when the latter pointed out that the stream pattern and barbed tributaries in the district of the Yangtze elbow-bends support the idea of capture (see Fig. 3A). This interpretation, afterwards put forward in print by both men,[4] has recently been confirmed through the more detailed work of Lee.[5] The beheaded river

[1] J. Blaeu, 'Aerdrycks Beschryving, II, Asia en China, Novus Atlas Sinensis,' Amsterdam, 1664.

[2] V. K. Ting, "On Hsü Hsia-k'o, Explorer and Geographer," *New China Review*, vol. 3, 1933, pp. 336–7 (in Chinese).

[3] J. Bacot, 'Le Tibet revolté,' Paris, 1912, p. 306.

[4] J. W. Gregory, *Geogr. J.*, vol. 61, 1923, p. 172. V. K. Ting, "Notes of a Geological Traveller," *Independent Review*, Peiping, No. 48, p. 11; No. 52, p. 16, 1933 (in Chinese).

[5] C. Y. Lee, "Development of the Upper Yangtze," *Bull. Geol. Soc. China*, vol. 13, 1933, p. 113.

is believed to be the Red River rather than the Mekong. Lee finds that the highest of the series of connecting depressions which now drain to the Mekong lies only 300 feet below the Kinpukou gap—a broad low saddle across which the Yangtze could have flowed before its last deep entrenchment. Elevations [1] along the route between Tali and Yunnanfu allow us to extend Lee's inferences farther to the south-east. In particular, of four depressions within 35 miles of Tali Lake (Erh Hai), the southernmost drains to the Yangtze, the next two empty into the Red River, while the last feeds the Mekong. The present elevation of three differs by less than 50 feet. They are separated by low open saddles, and according to Loczy's map [2] the Mekong–Red River divide on this line is only 300 feet below the Kinpuku gap (Fig. 2).

Fig. 2. Drainage near Erh Hai (Yunnan)

A similar capture must have diverted the headwaters of the ancestral Yalung-kiang. The suggestive drainage pattern is supported by the physiographic notes of more than one observer. Lee has reconstructed the precapture river system on this assumption, and the sketch-map (Fig. 3B) has been drafted along the lines indicated in his paper. The points marked by a cross (X) would repay a visit as further possible sites of diversion. A striking feature which attracts the attention of all travellers through this area is the height and steepness of the walls of the gorges in which the Yangtze is entrenched. Before rejuvenation the river had developed an open mature valley in marked contrast to its present rugged canyon. Near the diversion points, entrenchment is of the order of 2000 feet. The older drainage system thus dates back to a time when the river was flowing at that relative height above its present level. Since then it has had time to degrade its channel by that amount. Above the zigzag stretch of its course the river pattern exhibits no such obvious signs of a complex history, but its relation to the Salween and the Mekong presents a more formidable problem. Yule's simile likening the great rivers of Tibet to the "thunderbolt fascis in the clutch of Jove" is of itself enough to arouse the curiosity of the physiographer. The facts that three great rivers converge without uniting, flow

[1] W. Credner, "Observations on Geology and Morphology of Yunnan," Liang-kwang Ti-chih Tiao-cha-so, spec. pub. 10, 1932, p. 8.

[2] L. v. Loczy, 'Wissenschaftliche Ergebnisse der Reise des Grafen Bela Szechenyi,' 1893 (Map B, VI).

parallel a short distance apart for hundreds of miles without losing their identity, and then separate to enter three different seas, demand a structural control of the first order, at least for the arresting parallelism.

Various explanations have been put forward to account for the meridional trend of the three great streams. It has been attributed to parallel consequent drainage, following sag-lines on a fluted surface of warping.[1] It has been regarded as a result of alpine folding connected with the Himalayan revolution.[2] Development of channels along parallel belts of weak rock on a peneplane or subdued erosion surface truncating folded structures has been suggested.[3] Rifting along fault lines has been advocated as the cause of

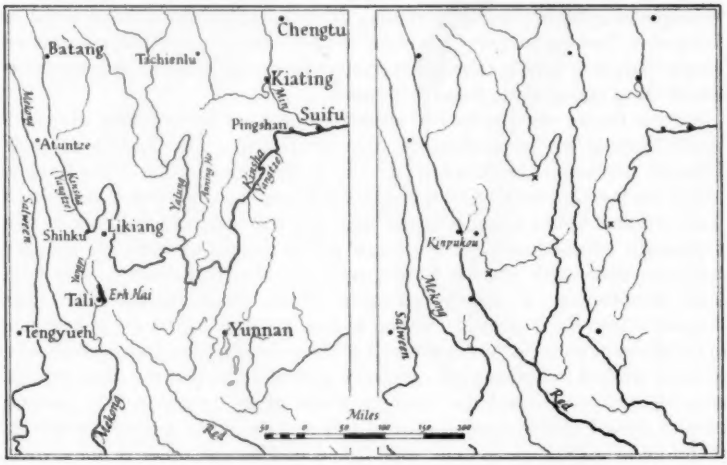


Fig. 3. River system of North Yunnan

parallel depressions which became natural spillways for melt-water from the Tibetan glaciers.[4]

It is probable that more than one of these factors was involved, but their precise relative importance can only be guessed at, and final decision between the various possibilities awaits further data. Meanwhile the evidence seems to support a modification of Deprat's general interpretation[5] of the great valleys as mainly directed by faults.

[1] C. Y. Lee, *op. cit.*, p. 113.

[2] Arnold Heim and K. Krejci-Graf, "Szechuan–Tibet Expedition," *Zeitsch. Gesell. Erdk.*, Berlin 1930, p. 269.

[3] W. Credner, *op. cit.*, pp. 10–13.

[4] J. Deprat, "Etudes géologiques du Yunnan oriental," *Mem. Serv. Géol. Indo-Chine*, vol. I, pt. 1, 1912, p. 225. J. Coggin-Brown, "Contributions to the Geology of the Province of Yunnan II," *Rec. Geol. Surv. India*, vol. 44, 1914, p. 98. J. W. and C. J. Gregory, "Alps of Chinese Tibet," *Geogr. J.*, vol. 61, 1923, p. 167.

[5] J. Deprat, *loc. cit.*

The issue has been somewhat confused as the result of Gregory's sponsoring a mid-Tertiary movement as the origin of the Nanling fold-system in South China. This he interpreted as an Asiatic counterpart of the Alpine Revolution,[1] striking obliquely across Yunnan towards the South China coast as an extension of the Himalayan folds. The earlier, late Palaeozoic, revolution was already well recognized. Without the guidance of fossiliferous horizons, Gregory assumed that there was no further folding until mid-Tertiary times. Hence a complicated history of peneplanation, uparching, faulting, and erosion had to be accommodated in post-Miocene time. Recently however Li, Tan[2] and Ting[3] have found evidence of late Mesozoic folding in west Szechuan and Yunnan, thus confirming the growing belief that the Yenshan folding was of widespread influence and importance. It appears that the oblique trend of Gregory's Nanling flexures is an older structure than he realized, and that an ample margin of time is thus left thereafter for the subsequent developments which the physiographic features demand.

Coggin Brown and Deprat had already pointed out the influence of north–south faulting in the drainage system of Yunnan. The finding of early Pliocene fresh-water molluscs in lake silts in the base of some of the troughs led to the assumption that all the deposits filling them were of that period.[4] Teilhard and Young[5] find however that in many localities the bulk of this supposedly simple formation is a coarse gravel deposit of distinctly younger age, associated with lateritic loams, overlying the fossil-bearing silts with local unconformity. Evidently vertical movement along pre-established lines continued into the Pleistocene Period and to it is due in part the persistence of the drainage pattern. While the bulk of these observations apply specifically to areas studied in Yunnan, the evidence goes to show that the same type of control extended beyond the northern limits of the province. The general picture gained of the development of this section of the Upper Yangtze is therefore of a drainage system, established in Pliocene times if not earlier, directed primarily along lines of structural weakness, and emptying through the Red River channel into the South China Sea. Some of the depressions are clearly of tectonic origin and do not owe their dimensions primarily to erosion. But judging from the contrast between the upland topography, which "hangs" relative to the youthful gorges, both the river channels and the topographic relief had attained mature forms in a previous erosion cycle before further uplift along the Tibetan border of Szechwan led to rejuvenation and capture. The extent and character of the glacial modifications appear to be of minor importance as far as the major lines of drainage are concerned. Little detailed work has been done however on this aspect of the problem. Further discussion of some of the inferred complications in the early stages

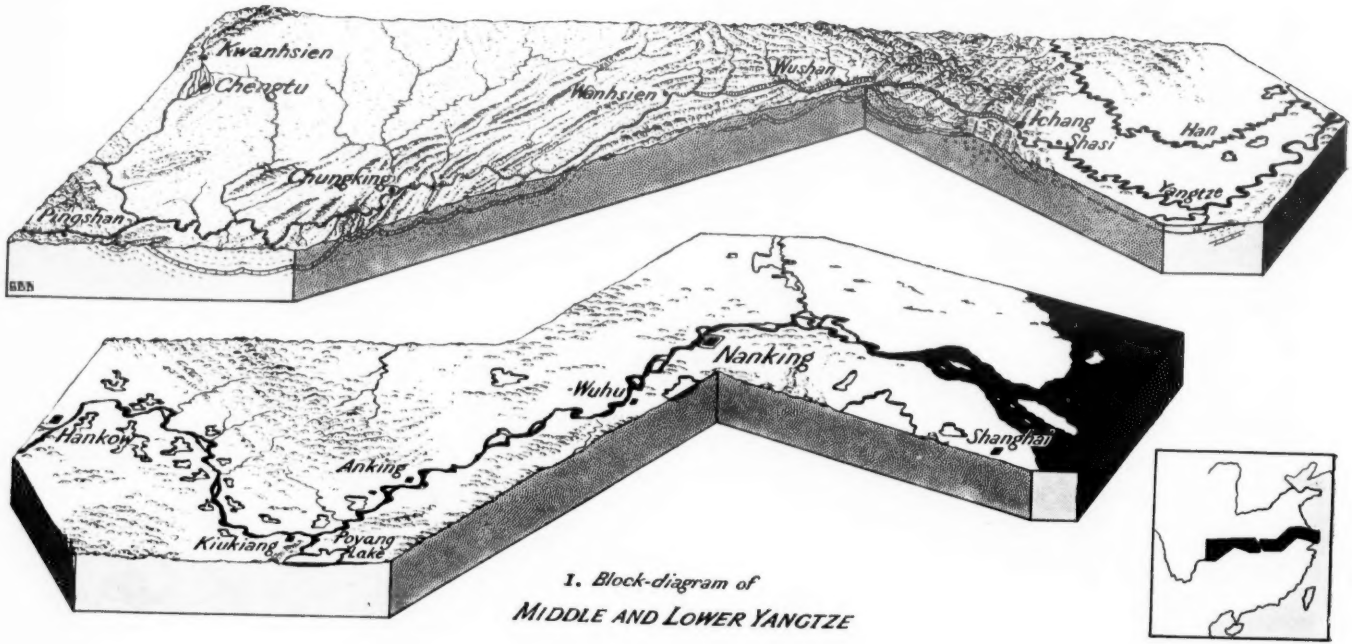
[1] J. W. and C. J. Gregory, "Geology and Physical Geography of Chinese Tibet," *Phil. Trans.*, Ser. B, vol. 213, 1925.

[2] H. C. Tan and C. Y. Li, "Mineral Resources of Eastern Sikang," *Geol. Surv. China*, Bull. 17, 1931, p. 2.

[3] Personal communication; see "Geology of Yunnan," *Geol. Surv. China Mem.* (in preparation).

[4] H. Mansuy, "Etude géologique du Yunnan oriental," *Mem. Surv. Géol. Indo-Chine*, vol. 1, fasc. 2, pt. 2, 1912, pp. 16–18.

[5] Personal communication.



1. *Block-diagram of*
MIDDLE AND LOWER YANGTZE

IIA. Walls of Windbox Gorge: 1500 ft. elevation

IIB. Anticlinal fold crossing Wushan Gorge: 1500 ft. elevation

of development and in the integration of the drainage network will be found in a publication of the Geological Survey of China.[1]

Middle Yangtze

Below Pingshan the history becomes clearer. The key to the problem lies in a correct understanding of the origin of the gorges. Wherever a river takes a course transverse to the underlying rock structures, the discordance points to some complication in its evolution. Various interpretations have been put forward for the variance between the direction of the fold axes and trend of the Yangtze in the gorges above Ichang. The popular explanation that the river found its way through gaps in ridges or along lines of structural weakness finds no support from field observations. Careful study of the summit lines of the ranges as seen from the air when flying over the gorges affords no support to this interpretation (Plate IIB). No control of this kind has been involved.

Integration of the drainage system through repeated capture by headward extension of master streams has been suggested by Willis[2] and other writers. While for a zigzag course like that of the Upper Yangtze above Pingshan successive diversions by capture are an obvious explanation, the same interpretation for a more direct stream like the Chialing-kiang [3] or the Middle Yangtze itself demands too exact a series of aligned coincidences to be readily credible.

Choice narrows down to two plausible explanations—***antecedence*** and ***superposition***. Either (1) the river was already sufficiently firmly established along its present line before the folds were buckled athwart its course, in which case flexing was so slow that the channel was kept open by erosion in face of unfavourable uplift; or else (2) the folding antedates the birth of the river, but the substructure, being subdued by erosion or buried under a cover of sediment, exerted little or no control on the initial choice of course.

(1) In discussing the last great fold trenched by the Yangtze across the Huangling anticline in the Ichang gorge, Willis and Blackwelder [4] speak of the antecedent character of this stretch of its course. Here they are referring to the fact that the moulding of the higher valley slopes proves that, after reaching maturity in a previous cycle of erosion, the river has been rejuvenated by a local upwarp across which it was competent to maintain its old course undeflected. But this statement has been often loosely taken to cover also the *original* adoption of the present trend—an unjustifiable extension of meaning which a careful reading of Willis's words does not bear out.

The failure of antecedence as an explanation is strikingly shown by the behaviour of the Talingho, a major tributary of the Yangtze, which enters from the north near Kweichow just above the Wushan gorge. This river as mapped by Abendanon[5] cuts across the strike of a series of five anticlines

[1] G. B. Barbour, "Physiographic History of the Yangtze," *Geol. Surv. China Mem.*, Ser. A, No. 14, 1935.

[2] Willis and Blackwelder, "Research in China," *Carnegie Instit. Wash. pub.* 54, vol. I, pt. I, 1907, p. 334. C. Y. Lee, "Development of the Upper Yangtze," *Bull. Geol. Soc. China*, vol. 13, 1933, p. 110.

[3] A. Heim, "Tectonical Sketch of the Yangtse," Liang-kwang Ti-chih Tiao-cha-so, spec. pub. 14, 1933, p. 22.

[4] Willis, *op. cit.*, p. 338.

[5] E. C. Abendanon, "Structural Geology of the Middle Yangtze Gorges," *Jour. Geol.*, vol. 16, 1908, map at p. 608.

with cores of the same resistant strata that build the walls of gorges on the Yangtze. It is inconceivable that five sharp folds could rise directly across the path of a tributary stream of this moderate calibre, with such uniformity and deliberation that it could hold to its channel without being thrown from its course by one or other of them. Apart from this, there is the belief, now gradually gaining acceptance, that the folding was of Yenshan age. The folds are thus of greater antiquity than the details of the present drainage system. And though during the protracted down-cutting process the river has adjusted itself locally to the substructure—as for instance where it makes a right-angle zigzag to take advantage of a belt of weak Cambrian shale in the Ichang gorges, or where it follows the strike of hard strata along the southern margin of the Red Basin—the transverse course in the gorges cannot be due to antecedence.

(2) The explanation by superposition seems to have been first explicitly proposed for the Yangtze by Kniep[1] in a paper mainly devoted to discussion of the river as an undeveloped waterway for steamer traffic, written some years before Captain Plant's pioneer attempts had made the dream a fact. Kniep's interest lay in explaining the origin of the gorges rather than in attempting to unravel the history of the river as a whole, and the topic is given such a minor place in the treatment that his contribution has escaped general notice.

Superposition may be of two types: (*a*) from an unconformable sedimentary cover, or (*b*) from a low-relief erosion surface or peneplane developed across flexures in a bedrock floor, and with only a thin cover of alluvium or loam.

(*a*) The absence from the entire region of remnants of any unconformable overlying formation makes superposition of the classical Appalachian type unlikely. It is possible that the imposing Tertiary conglomerates which once extended some miles west of their present boundary at Ichang actually reached to the Red Basin, but in view of their resistant character it is hard to account for their being stripped off with such thoroughness that no trace of their former presence can be found.

(*b*) The remaining hypothesis of superposition from a thinly veneered peneplane calls for two conditions: (i) the folds must date from a sufficiently ancient time for peneplanation to have occurred since—which is possible if the buckling was of Yenshan (late Mesozoic) age; and (ii) the maximum summit levels of the ridges should show a consistency of skyline across truncated structures, and locally an accordancy of crest line, in keeping with the idea of a dissected peneplain which has only undergone slight warping and reduction by erosion since its development (Plate III). Both of these conditions are fulfilled along the Middle Yangtze.

Explained on this basis, the discordant path of the Middle Yangtze becomes intelligible. Along much of its length there has been time for extensive later adjustment of course to substructure, so that the river now parallels the folds along belts of weaker rock. But where it was let down squarely across a resistant barrier no evasion by migration down the dip-slope was possible, and the channel has remained pinned to gaps cut through the gorge-building strata (see Plate II).

[1] Arthur Kniep, "Der Yangtze als Weg zwischen den westlichen und östlichen China," *Gerlands Beiträg. z. Geophysik*, vol. 7, 1905, pp. 1–31.

The steady down-cutting process has not been entirely without interruption. At least twice the river cut down to grade and had begun to widen its channel when rejuvenation forced it to trench further. On the first occasion the valley walls had already assumed open mature forms, the remains of which may still be detected in places as discordances of slope, now perched at heights of 600 feet or so above river-level (see air-view, Plate IIA). This ancient mature surface corresponds to the "Tsinling stage" noted by Willis and Blackwelder

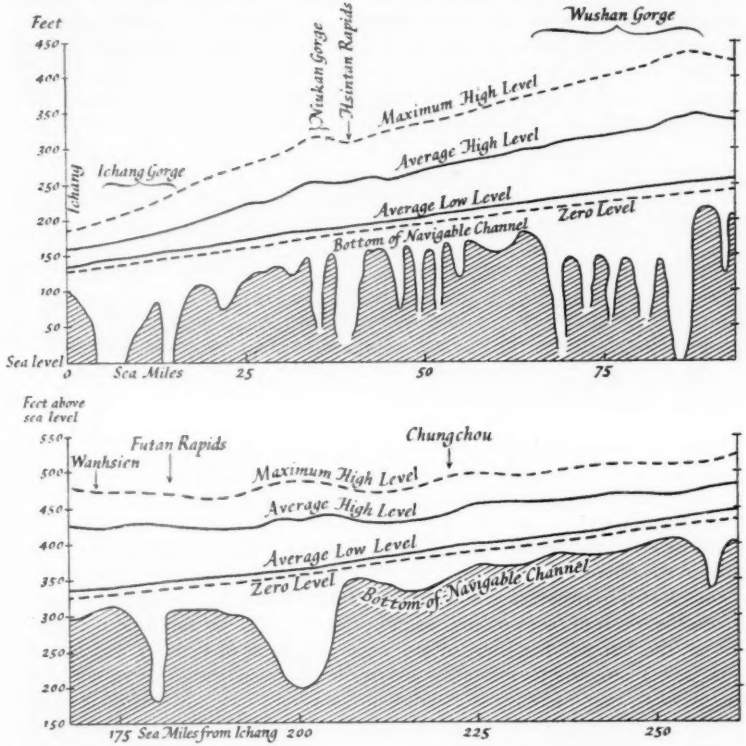


Fig. 4. Profile of two 95-mile stretches of the Middle Yangtze (Redrawn from Plant's "Handbook for Guidance of Shipmasters")

in northern Szechwan. It is only with respect to the grading of this epoch that the later channel may properly be called antecedent. The second interruption was much briefer and is recorded merely in alluvium-capped rock terraces 50 to 100 feet above the present mean water-level.

In view of the spectacular high-water rise at flood time—in the Wushan gorge it reaches 200 feet—one might take these terraces for no more than flood-plain terraces of the present cycle. Careful checking against the high-water records of the ninety-five Maritime Customs gauges however proves

that this is not the case, and shows that the terraces belong to an interrupted previous erosion cycle. If further proof is needed, it lies in the present extreme unevenness of the river bottom, which is far from being maturely graded. The profiles in Fig. 4 are based on the Maritime Customs Survey [1] and show the stream-bed and water-level surfaces over two 95-mile stretches of the Middle Yangtze. It will be seen that at one point in the Wushan Gorge the bottom of the channel is actually below sea-level. Corroboration is found in the erosion surfaces within the Red Basin itself and in the "hanging" character of some of the lateral tributaries. Observations bearing on this point were made during the course of a recent expedition undertaken by the writer in company with Drs. P. Teilhard de Chardin and C. C. Young at the request of the Director of the Cenozoic Laboratory. The evidence will be found in the report already cited.[2]

Lower Yangtze

For 60 miles below Ichang the Yangtze cuts through a foothill belt of sandstone and gravel on the west border of the Hupei depression. Here the

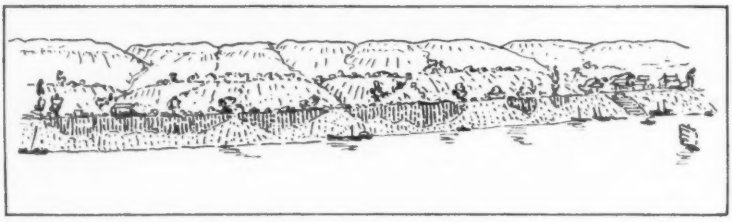


Fig. 5. Field-sketch of terraces below Ichang

channel has the characteristics of early maturity, with an embryo flood plain within the curves of a developing meander system, but with lateral cutting of bedrock still in progress at the outside of each bend. Loam-capped terraces mark the levels of two earlier erosion cycles (Fig. 5). By the time it reaches Shasi, the Yangtze has escaped from the constraint of bedrock and is fully mature. Thereafter its meanders are free to swing on a wide floodplain, only occasionally coming in contact with bedrock where its course carries it to one margin or the other on the meander belt. At a few points farther down stream the river is pinned to nodes between projecting rock ridges, the most noteworthy being at Hankow and Nanking, where its course is strictly confined. Elsewhere the abundance of lakes and poorly drained marshes testifies to a subsidence which has submerged all traces of former relief. Evidently the down-sag responsible for these features is so recent an event that the river has not yet had time to silt up the depressions.

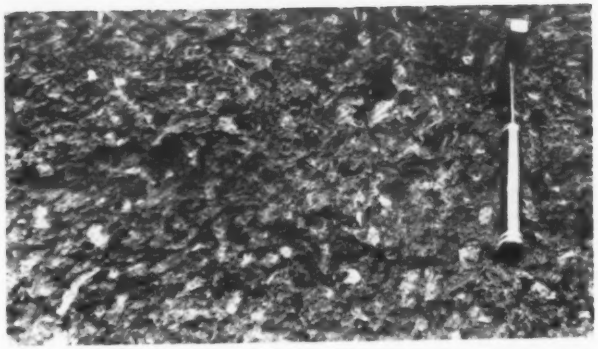
As is clear from Fig. 1 and the block diagram (Plate I) the series of connecting depressions occupied by the Yangtze follow the structure-lines of the ranges which flank them. The folds of these ranges date back to the

[1] S. C. Plant, "Handbook for Guidance of Shipmasters," *C.M.C. spec. pub. No.* 34 (2nd issue), Shanghai 1932, p. 5.

[2] G. B. Barbour, *Geol. Surv. China Mem.*, Ser. A, No. 14, 1935, pp. 30–40.

IIIA. Ridge of truncated strata and skyline profile 100 miles E. of Wanhsien

IIIB. Even crestline from N. of Ichang. Cultivated river terraces in foreground



IV A. Laterized clay with vermicular mottlings (Kinkiang)

IV B. Hard cellular crust over laterized formation

Col. Charles Lindbergh Photo

IV C. Yangtze flood at Hinghwa, N. Kiangsu, 1931

Col. Charles Lindbergh Photo

IV D. Grand Canal, Yangtze crevasse, 1931

IVc. Yangtze flood at Hinghwa, N. Kiangsu, 1931

IVd. Grand Canal, Yangtze crevasse, 1931

Yenshan movement. Upheaval of the mountains then, and minor crustal readjustments thereafter, furnished vast quantities of coarse detritus which came to rest in the intermont basins, entirely burying the lower ground under a thick apron of sand and gravel. But later warping was influenced by the pre-established control, so that the drainage has kept the same general trend since early in the Tertiary Era.

Mention has been made of two sets of river terraces well seen just below Ichang. Crossing the Hupei depression they are lost sight of, having sunk below the level of the plain. But farther downstream, wherever buried ridges project above the alluvium near the margin of the basins, and still more obviously where the Yangtze abuts the foot of mountainous areas, this double system of terraces comes again into evidence. The present elevations of the terraces vary slightly from point to point, depending on the character and amount of local warping in different localities. They can be seen from the boat at several dozen places and may be studied with special advantage at the river ports of Kinling, Kiukiang, and Anking (see Fig. 6). The deposits that build these terraces are distinctive and not only afford valuable clues

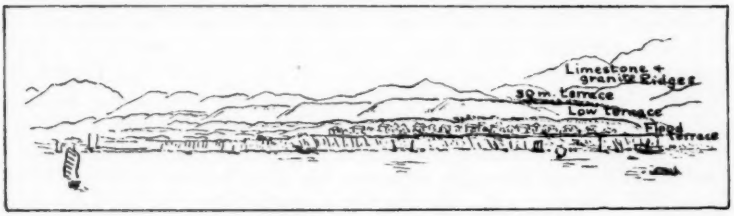


Fig. 6. Field-sketch of terraces near Anking

as to past climatic changes, but serve also as a means of correlation with similar land forms over much of Central and South China.

Raised above the present flood-terrace is the low-terrace system of the penultimate cycle.[1] If we reconstruct the once continuous platform of which the terraces are dismembered remnants, it is seen to be a valley-floor deposit with a gently rising marginal fringe whose projections interfinger the higher ground on both flanks of the main depression. In many places these lateral

[1] It should be noted that in North China many of the streams have been rejuvenated four times since the early Tertiary peneplanation. After each return to youth, they again achieved maturity, at least over considerable stretches of their courses. The intervals however have always been too brief for the regional relief to be again reduced to a peneplane. All the cycles of erosion are therefore interrupted or incomplete as far as the general land surface is concerned, although the streams may have passed through youth and early maturity to a graded condition. Their marked seasonal variation due to monsoon conditions, coupled with the loam-covered character of the terraces they dissect, involves a heavy silt discharge and has after each rejuvenation led to extensive alluviation of all the bottom-lands and the development of a gently graded rainwash and loam cover extending back accordantly from both sides of the main channels to the flanking higher ground. For brevity therefore it has become usual to refer to each of these well-established interrupted or partial cycles simply as cycles. The same applies to the Lower Yangtze and the word must be so understood in referring to what Mr. J. M. Wordie has aptly termed these "cycles of Cathay."

embayments are obviously erosional features cut in the high-terrace system, a still older, more fragmentary land form whose restored summit-levels conform to the general drainage slopes of the two more recent partial cycles. The surface is veneered with the same ubiquitous buff-coloured loam that covered all the lower ground at the end of the second cycle. But the high-terrace cores are of lateritic material which records weathering effects of a different kind, typical of Pliocene and Lower Pleistocene deposits from Yunnan to Honan.

Though v. Richthofen's Atlas shows "laterit" at a number of points in the Lower Yangtze basin, the formation has remained almost without further notice until now; only after fifty years is its significance being realized. Chemical study will probably show that it is not a true laterite *sensu stricto*, but belongs rather to the group of lateritic earths. Whatever the precise composition however, there is no question as to the type of weathering involved in its making, so that the term "laterization" may be safely used.

The present texture and consistency of the laterized deposit varies from place to place, depending partly on the original character of the parent material attacked by this deeply penetrating alteration, partly on changes which it underwent during the ensuing epoch of different ground-water conditions. The commonest variety is a brick-red impure clay with grey or bleached vermicular mottlings (see Plate IV, Fig. A), often with a hard cellular crust two feet or more in thickness. The crust itself (Plate IV, Fig. B) is evidently a secondary effect, developed in the laterized material by later deposition of silica as a hardpan layer beneath the original surface of the ferruginous mass. Occasionally a capping of the softer overburden is still found *in situ*, but in most places the formation has been stripped down to, if not below, the indurated zone. The cavities in the cellular crust correspond to the grey vermiculations of the deeper zone, and presumably began as rootlet holes and capillary channels along which the iron of the lateritic material was later reduced and leached by percolating soil water, thus weakening the cementing material and facilitating its removal. The result is the "worm-eaten" appearance well seen in the picture. It would be out of place here to discuss the precise causes of changed ground-water action which gave rise to the vermiculations and the hardened cellular layer in the laterized deposits. Physiographically these features may be assigned to a late substage in the main high-terrace cycle. The one feature common to all the deposits dating from the high-terrace epoch is this intense weathering under tropical conditions quite unlike those of the two later cycles. We saw evidence of it throughout the Lower Yangtze basin and it extends north into Honan. Teilhard and Young have recently reported the same feature from the Pliocene and Lower Pleistocene of Yunnan and Kweichow. Even where the effects are less extreme, symptoms of an analogous tendency may be detected. In Central Honan for instance, beneath a calcareous subsoil formed under conditions akin to those of to-day, a layer of scattered black pellets, the size of small peas and rich in iron and manganese, is often found overlying reddish clay in which similar pellets are embedded in less regular arrangement. The pellets contain iron and manganese and are pisolitic concretions produced by the same process, the richer layer marking a former ground-surface on which they concentrated as the rest of the deposit was worn away by erosion.

Young and Bien have recently reported the same feature from Shantung. Going farther north, it is significant that the mammal fossils from the late Pliocene and early Pleistocene horizons, including the *Sinanthropus* (Peking Man) fauna, indicate a warmer climate in North China than has ruled at any time since the Middle Pleistocene. Thus the extension of the evidence into other districts serves as a valuable control on the correctness of the interpretation of the Yangtze valley history itself.

The Lower Yangtze basin, then, had its broad outlines determined by structures established at the close of the Mesozoic Era. These latter exerted a persistent control on the distribution of Tertiary sedimentation. By the close of the era, erosion and valley aggradation had reduced the land surface to a relief slightly gentler than that of to-day, under tropical conditions of weathering which persisted well into the Pleistocene period. Warping rejuvenated the rivers, and the sedimentation which followed their attainment of maturity took place under climatic conditions more like those of to-day. The corresponding deposits of North China indicate a late Pleistocene climate actually colder and more rigorous than to-day's. A second rejuvenation led in turn to dissection of the lower terraces. It is not clear just how closely the warping which raised these terraces to their present elevation was related to the down-sag responsible for the ponding in the depressed areas. They may be complementary expressions of the same crustal adjustment, but the subsidence is certainly a comparatively recent event; in fact, there is no reason to suppose that it has entirely ceased.

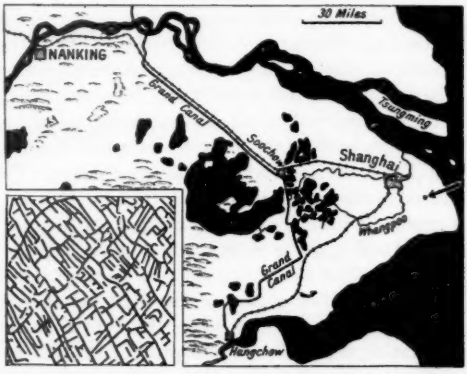


Fig. 7. Southern portion of Yangtze delta. Inset shows canal and dyke system of the square mile indicated by arrow near Shanghai (after "Whangpoo Conservancy Report")

The Yangtze Delta

The poorly drained character of the delta area is sufficiently evident from the maps of the area made by the Whangpoo Conservancy (Fig. 7).

There is abundant evidence that the delta-front is pushing steadily seaward. From the dates at which sea-coast communities occupying reclaimed land became organized units and first appeared on the ancient tax rolls, Ting has deduced an advance of 1 mile in 69 years.[1] This tallies closely enough with Von Heidenstam's estimate of 60 miles, based on the annual rate of silt discharge.[2] The average yearly advance is thus about 25 yards.

[1] V. K. Ting, "Geology of the Yangtze Estuary," *Shanghai Harbour Investigation*, Ser. 1, Rep. 1, 1919, p. 77.

[2] H. von Heidenstam, "Growth of the Yangtze Delta," *Jour. N. China Br. Roy. Asiat. Soc.*, vol. 53, 1922, p. 21.

The part played by warping in the seaward advance of the coastline is not yet clear. Extension of the land area of a delta may occur not only on stable coastlines and those of emergence but even on coastlines where subsidence is still taking place provided sedimentation is rapid enough. In fact the embayed outline of Fukien points clearly to subsidence. The isolated half-submerged hillocks of the Chekiang plain and the pebble deposits struck in well-borings at a depth of 900 feet beneath Shanghai [1] demand a similar explanation, but furnish no evidence on which a dating can be based. River gravels 140 feet below ground-level at Nanking [2] definitely indicate submergence to nearly that extent since Lower Pleistocene times.[3] Strandline shifts have certainly been oscillatory and it is not easy to isolate the various factors responsible for relative rise and fall of sea level. The convergence of evidence points to crustal warping as the effective process, with subsidence as the dominant movement in the delta area since well before the close of the Tertiary Era.[4] Sinking was probably irregular, halted for a time, or even had its effects negatived by eustatic shift or epeirogenic movement in the Middle Pleistocene, and proceeded at an extremely slow pace thereafter. Whether or not it has actually ceased remains an undetermined question.

Outline of Evolution of the Yangtze

We are now in a position to review in outline the evolution of the river. Fig. 8 shows in diagrammatic form some of the main tectonic events that affected the middle and lower basins. Late in the Cretaceous period, eastern Szechwan was a basin receiving sediment from a peripheral mountain belt raised under the influence of late Mesozoic crustal disturbance. At the close of the era, and with waning intensity thereafter, the last spasms of the Yenshan movement buckled the margin of the Red Basin and adjacent parts of Yunnan and Tibet, causing radical drainage changes. The centre of subsidence then shifted to the east, depressions forming in Central Hupeh and along the Lower Yangtze. Middle Tertiary movements were limited to faulting, warping, and vertical uplift, being most marked in the far west. By Middle Pliocene times a well-developed drainage network was in existence, the upper waters of the present river being part of the Red River system, and the run-off from Szechwan draining east along the course of the Middle Yangtze. Barbed tributaries, sharp elbows of capture, and wind-gaps connecting with perched mature topography of an older cycle, mark the course in Yunnan where the pattern of mid-Tertiary faulting, transecting more complex late Mesozoic structures, had fixed the major stream courses. By headward extension under the influence of uplift to the west, one of the middle-basin rivers captured a feeder of the Red River. This was the first of a series of diversions which finally turned the entire Upper Yangtze supply into the eastern system. The diversion is tentatively placed early in the Pleistocene period, but may have taken place shortly before the close of the Pliocene.

[1] Walker, *Proc. Eng. Soc. China*, vol. 25, paper 5, 1926, p. 14. See also G. B. Cressey, *China Jour.*, vol. 8, 1928, p. 334.

[2] C. Y. Hsieh, *Bull. Geol. Soc. China*, vol. 9, 1931, p. 61.

[3] G. B. Barbour, "Geomorphology of the Nanking Area," *Acad. Sinic. Nat. Res. Instit. Geol. Contrib.* 3, 1933, p. 121.

[4] G. B. Barbour, *Geol. Surv. China Mem.*, Ser. A, No. 14, 1935, Chap. VI.

The Middle Yangtze is superposed from an early Tertiary peneplane—later warped and dissected to mature valley forms—on folded strata of varying resistance. Further differential uplift—possibly coincident with the movement in the west which led to the Upper Yangtze diversion—rendered the river antecedent in the Ichang gorges, and elsewhere caused simple rejuvenation. A pause in the trenching occurred during the later Pleistocene. Apart from this the story is one of fairly steady downcutting.

The Lower Yangtze has a very different history. It occupies a consequent channel in a warp-depression that has remained relatively near sea level since early in the Tertiary era. The Middle Yangtze is only one of a number of

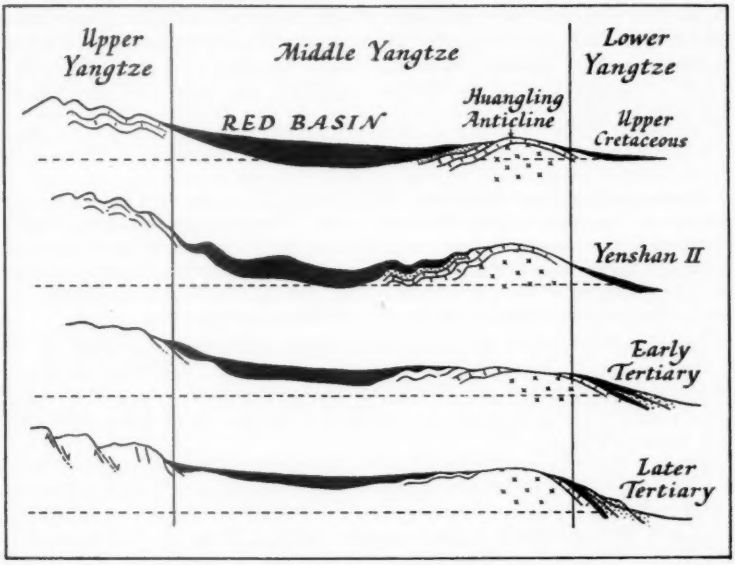


Fig. 8. Stages in development of Yangtze basin

rivers that found a natural outlet into the resulting basin. Terraced deposits show a uniformity of character along these contributing arteries which allows us to correlate them with the late Pliocene and Pleistocene rejuvenations throughout the system.

Regarding the future course of events we can only hazard a qualified guess. The delta is pushing seawards faster than its effects are being offset by any present subsidence of the coast, and the entire east fringe of the North China Sea is evidently slowly becoming shallower. In the lake areas of the Lower Yangtze basin comparative soundings in the last three decades have been limited to the navigable channels and only one areal charting has been attempted. Hence there are no precise data showing the progress of shoaling in areas of standing water. It is commonly said that slow silting has been noted by the older inhabitants of villages on the edge of Tung Ting Hu, and

it may be inferred from the elevations of the terraces that the lakes are in process of slow extinction.

The Middle Yangtze is again approaching maturity along stretches of its course, but to the west occasional minor earthquake shocks show that the forces causing uplift are not yet spent. Eventually further redistribution of the Tibetan headwater supply may be anticipated. According to Ward,[1] just south of lat. 30° N. the Salween is actually working at a considerably lower elevation than the Mekong and Yangtze at its side. Because of their deeply entrenched positions none of the three loses or gains by the handicap. But if crustal movement wanes, or stays in abeyance long enough for their tributaries to win to maturity, the Yangtze will have a competitor whose shorter course to the sea, and more favoured position with regard to rainfall, will give it an advantage. This may ultimately lead to capture, history repeating itself when maturity is again attained. If so, the Upper Yangtze, once draining to the Gulf of Tongking and to-day joining the Yellow Sea, may eventually flow to the Indian Ocean.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: The subject of the lecture this afternoon is the "Physiographic History of the Yangtze." Mr. George Barbour is to address us. He has spent many years in China studying the geology of the country and is well equipped to explain to us the physiography of these great rivers, the Mekong, Salween, and Yangtze. It is the Yangtze that is his particular subject this afternoon.

Mr. Barbour then read the paper printed above, and a discussion followed.

The PRESIDENT: We have here this afternoon Dr. J. S. Lee, Director of the National Research Institute of Geology at Nanking, who is spending some considerable time in England. I will ask him to give us his observations on Mr. Barbour's paper.

Dr. J. S. LEE: I consider it my great good fortune to have been able to hear Dr. Barbour on this problem in which I myself happen to be immensely interested. It is also my pleasure to compliment Dr. Barbour on his interesting discourse on the very vast and rather complex problem of the river Yangtze. Dr. Barbour, with whom I had the pleasure of working for over ten years, is one of those happy persons who are able to sketch natural features, a very useful gift when at work in the field and one which helps to bring the matter more lucidly before an audience than does the product of the camera. He has given us a pictorial exposition of his hypothesis.

I have no personal knowledge of the Upper Yangtze beyond the gorges as Dr. Barbour has laid out before us, but I have some slight knowledge of certain regions connected therewith, in particular the Nanling elevations, a mountain range which is of considerable importance so far as South China geography is concerned. This is the range which separates the Yangtze from the Sikiang and its allied rivers. It is roughly an east–west mountain range. I happen to have visited the part of the range more to the east, namely the part in the south-west of Hunan Province and the north-east of Kwangsi. There, the mountain ranges generally run north-north-east and south-south-west. The Five Mountain Ranges run almost like the fingers of the hand, and they are, so to speak, tied together in a knot to form that part of the Nanling. These five ranges, having

[1] Kingdon Ward, 'Land of the Blue Poppy,' 1913, Cambridge, p. 257.

their axes running north-north-east and south-south-west, are cross-folded with, roughly, an east–west axis. It is that east–west axis which causes the separation of the Yangtze basin from the Sikiang Valley.

I must not go into the matter of the foldings, but that particular axis would seem to correspond to the axis which I think was spoken of by the late Professor Gregory at about 26° north. Probably there we have some example of the uplifting of which Dr. Barbour has spoken. That is the only case I recollect which affords evidence of the separation of the Upper Yangtze.

If I may add a word on another point, it would be about the evidence of the deposit found in the lower part of the Yangtze river which the lecturer has mentioned. As he has pointed out, these clays are partly lateritized, but there are certain facts which seem rather to indicate periods of lower temperature, and may possibly relate to the operation of accumulated snow and ice coming from higher altitudes. I am not going to enter into the evidence for this, but I would like to point out, for instance, the snow-line in western Szechwan. The small glacier near Kuanhsien now stands at an altitude of about 4800 metres, but in former days it came down to an altitude of about 3000 metres. Similar evidence seems available in northern Yunnan, where a lowering of the snow-line amounts to about 2000 metres in relatively recent geological times. We have no positive evidence to show that the retreat of the small glaciers is entirely due to desiccation. On the other hand evidence has been gathered which indicates that a considerable uplifting has been experienced by the region of Sino-Tibet. In other words, we have had a more extensive glaciation than we have to-day in that part of the country. Thus it is not impossible that there may have been some violent changes of climate.

I thank you, Sir, for giving me the opportunity of complimenting Dr. Barbour on his enlightening lecture.

The PRESIDENT: Dr. Sandford, of the Geological Department at Oxford, who has often been on this platform, is with us this afternoon, and perhaps he would like to add a few words to the discussion.

Dr. K. S. SANDFORD: I should like to congratulate Dr. Barbour on this interesting paper. Apart from the general value of this work, there are a number of points which one would like to discuss in detail, but that would take up too much time. I will mention only one or two that have occurred to me. Among other things, I should like to congratulate Dr. Barbour on his valuable photographs taken from the aeroplane coming down the gorge. These showed a number of important features, and perhaps the most important was the bevelling to which he directed our attention. When we see from the air the surface of the ground cutting clean across the structure, hard beds and soft beds alike, we may be sure that some point of particular importance is to be observed on the ground, and I have no doubt Dr. Barbour has this in mind among other localities for further research.

Another interesting thing was the contour of the bottom of the river bed. So much work on rivers relates only to the surface of the water, and it is only now and again that we are able to refer to the contour of the bottom of the river. The contour which he showed us indicated intense localized erosion along certain courses of the river-bed. It is probable that still deeper channels are filled up with debris, and therefore do not appear in the profile. The same feature turns up far from the sea, in the Nile, where some profoundly deep channels have been found when the question of placing barrages across the river has been considered, and they are a serious matter to the engineers. They are in fact characteristic of the passage of great bodies of water through a narrow gap where therefore they must cut down below the normal level, or even below sea-level.

A word should be said on the subject of the terraces. I should like to ask Dr. Barbour whether he thinks that the terraces are formed at periods of annual high water, or only at normal low water of the rest of the year. My own opinion is that in many rivers they take their form during the major part of the year, and are probably not much altered during flooding. I do not know what the evidence may be in the case of the Yangtze.

Finally, I imagine that laterization took place in the terraces when soil was formed. I am not quite clear whether Dr. Barbour considered the laterization to take place during terrace formation or afterwards. In my opinion it must have taken place subsequently as it is essentially a soil process.

The PRESIDENT: Mr. Barbour is to complete his paper this afternoon by showing to those of us who can remain a cinematograph film in colour. Before this however I will ask him to make any remarks he may wish on the discussion: and I will put a brief question to him myself, and ask him whether the excavations in that part of the Yangtze with which he has been dealing uncovered any traces of the Peking man.

Dr. BARBOUR: I think that the colour-film I am about to show will answer one or two of the questions raised in discussion. I may say that it consists of two 400-foot reels of Kodacolor and shows features of a journey up the Yangtze river. The precise mode of origin of some of the surface deposits is still a matter of debate, as Professor Lee has indicated. If any of them are actually of glacial origin, as he suggests, the laterization itself still calls for warmer rather than colder climatic conditions for the development of the features which all the deposits of the high-terrace stage exemplify.

With regard to Dr. Sandford's question, I agree that laterization occurred subsequent to the building of the terrace. Perhaps I did not make that clear. It is obviously a soil phenomenon, and the matter has to be considered how far the high terraces are a depositional or an erosional surface. In the main the original terrace surface was depositional.

With regard to Dr. Sandford's query as to whether, in the gorges, the terrace deposits are formed when the stream is at high or at low water, the answer must be that this deposition takes place at or just after high water: only then does the river-level come within tens of feet of the deposits involved.

As to the President's question—at the only likely place where we hoped to find associates of the Peking Man, the results were negative. These have been recorded by Dr. Young. No evidence of man was found, though some mammalian remains found show a relationship with those of the period in which the Peking Man lived in North China.

Dr. Barbour described the scenes along the river as the films were projected, and at the close the thanks of the Meeting were given him.

SOME NOTES ON THE NORTH NORFOLK COAST FROM HUNSTANTON TO BRANCASTER: *A supplement to the paper on Scolt Head Island (Geogr. J., June 1934).*

J. A. STEERS

THE stretch of shore discussed presents many points of interest, and is in several respects similar to Scolt Head Island. But conditions have been such that no dominating structures like that island have been formed. Man has played a part in the building of sea-walls and in other ways, and so has modified the natural factors at work. Unfortunately too this piece of shoreline is, for the most part, badly documented. Old maps are scarce, except for Holme, and when found they often throw little light on recent changes. Consequently information has to be gleaned from a study of the shore features themselves, and as many of these are rather ephemeral structures it is difficult to interpret the past changes which have taken place. The main value of this note is to describe the features of the present coast, illustrating as far as possible their mode of origin for the benefit of future workers. Detailed mapping of certain parts has already been carried out, and the future changes should be of much interest, because alterations take place rapidly, and some of the features throw much light on the origin of bigger land forms such as Scolt Head Island.

One further point needs emphasizing. The features along the north Norfolk coast testify clearly to the fact that, although they may be consistent, no simple generalized explanation accounts for them. Shingle and sand spits point both east and west, and cannot be explained by any general hypothesis postulating a drift of beach material in one direction.

It is worth remarking that Thornham and other places on this shore were, up to about the middle of last century, relatively important ports. It is still remembered in Thornham that the road leading to the old granary was, in harvest time, lined with carts waiting their turn to load ships at the quay. When the railway from Heacham to Wells was built this trade was reorientated, and until the development of motor cars and the rebuilding of the roads, this part of Norfolk was comparatively unknown.

Holme and Gore Point

Early maps of this part of the coast make it clear that the present Holme salt marsh (*i.e.* the Lavender marsh) has developed since 1797, probably since 1860. The general evolution has been somewhat as follows.

On Bryant's (1826) and Faden's (1797) maps of Norfolk the inner line of sand dunes (*i.e.* on the south-eastern side of Holme salt marsh) is marked as a continuous line from the cliffs at Hunstanton to Gore Point and eastward as far as the north–south bank which shuts off the reclaimed Holme marshes from Thornham open marsh. Precisely what the appearance of this line of dunes and shingle was it is not possible to say. To the north-west of this bank these maps mark an area called Holme Scalps, probably a series of mussel beds and shingle as suggested by A. S. Marsh.[1] Within these scalps is shown a well-defined channel which is apparently the direct ancestor of the present

[1] *Journal of Ecology*, 3, 1915.

channel draining the salt marsh. Since Faden's time this inner line of dunes has become more concave.

The Holme Enclosure map of 1827 [1] suggests much the same state of affairs. Only the line of the inner dunes is marked. Low-water mark is distinctly drawn, but no outer hills are shown. Gore Point projects westward, suggesting local growth in that direction and so supporting the view that the ridges from Hunstanton met an off-shore bar formed off Broad Water (see below). This implies that the present Holme salt marsh is a development since 1827 at the earliest (see later). It is possible that by this time, even if not earlier, incipient shingle banks had begun to form which were later to develop into the outer line of to-day. But no such indication is given on a later map (1858) dealing with Holme Enclosures. The same inner line of dunes is shown, and without them "The Sea" is clearly marked. This map however presents many points

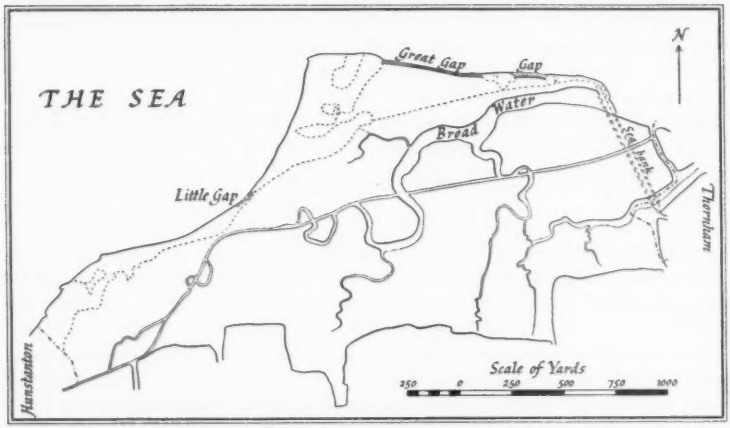


Fig. 1. Enclosure Map of Holme, 1858. The original is in the possession of Mr. Simms-Reeve of Holme-next-the-Sea

of interest. It makes it quite clear that the present line of dunes running east from Gore Point to Thornham Bank is not entirely natural. The part marked Great Gap was then an artificial mud bank which was destroyed by the storm of 30 November 1897. A little later this part was rebuilt on a wooden framework reinforced with clay. On this new bank dunes have accumulated and marram has thriven. The part marked Gap is also partly artificial, but again dunes have spread over it.[2] We may, then, presume that before these artificial banks were built there was a tendency to natural ridge and dune formation, just as there is a little farther east at Thornham to-day. But the natural banks had to be strengthened before any reclamation could be effected.

The bank running north and south and shutting off Holme reclaimed marsh

[1] This map is in the offices of Messrs. Partridge and Forster, Solicitors, King's Lynn. I do not know of any other copy. The Enclosure Map (Fig. 1) of 1858 is very similar to the earlier map, but shows the artificial parts of the banks and also the straightening of the River Hun. It omits inland details of properties, etc.

[2] Both these gaps are absent from the 1827 Enclosure Map: this suggests that first a natural line of shingle ridge and dunes existed which was later broken through and mended artificially—only to be broken again in 1897.

from Thornham was built in 1860. Just within this bank is a lake-like expanse called Broad Water. This is really part of the old marsh channels which drained eastwards, as shown on Bryant's and Faden's maps and the first edition of the 1-inch Ordnance Survey Map (1824). The river Hun, which runs from Old Hunstanton inside the Golf Course, is in a channel which is mainly artificial. This stream used to drain directly into the Broad Water and so to near Thornham, but when reclamation works were carried out it was straightened and given its present course.

The inner bank of Holme salt marsh has been altered artificially to some extent. The stretch marked Little Gap on the enclosure map indicates a constructed bank in this place which is still intact.

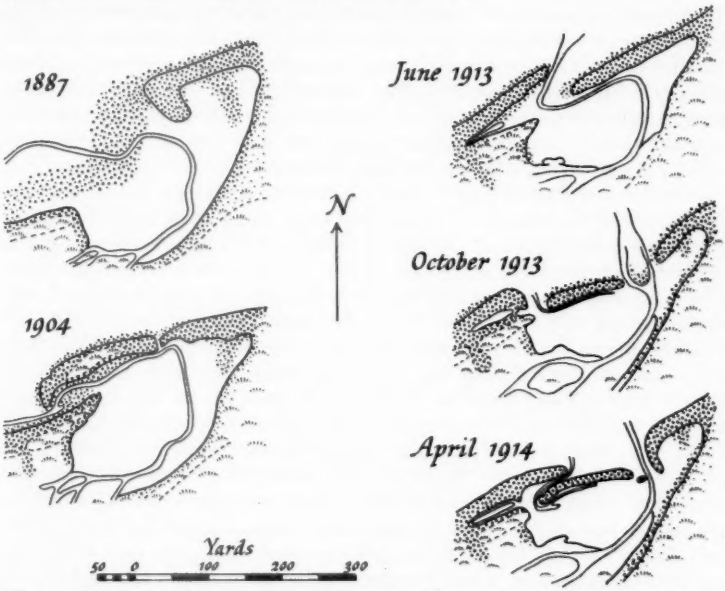


Fig. 2. Stages in the recent development of Gore Point. (*Based on A. S. Marsh, op. cit.*)

A century ago therefore Gore Point was a more pronounced feature than now. It consisted of a headland of sandhills, and the enclosure maps of 1827 and 1858 suggest traces of one or more recurved ends. Since that time Gore Point has suffered a good deal of erosion, but it is really only since about 1885 that it has been noticeable, because a trigonometrical station established well away from the sea in 1887 had disappeared by 1913.[1] Erosion is now concentrated at this point; a little farther east the dunes are growing well, and not far to the south-west the dunes of the Golf Course are prograding. Erosion is probably aided by the fact that Gore Point forms a salient in the shoreline, and also because the channel draining Holme salt marsh debouches at the Point, giving rise to a good deal of local scour.

[1] A. S. Marsh, *loc. cit.*

It is not possible to say exactly when the new ridge on the seaward side of the salt marsh began to form. As indicated above, incipient ridges may have accumulated on Holme Scalps well before they were marked on maps. The present ridge has not had by any means a simple and unchequered career. The following sketch-maps [1] taken from Marsh's paper, show that shingle ridges have grown outwards from Gore Point as well as from the direction of Hunstanton. This is first seen on the Ordnance Map of 1887. In 1904 (see current edition of 6-inch map) the south-westerly growing ridge had been stable enough for a small dune to grow upon it. Since then changes have been rapid, and at the present time there is no ridge growing from Gore Point, but this point is suffering serious erosion. On the other hand, the ridge enclosing Holme marsh is a direct continuation of those nearer Hunstanton, and has apparently grown eastwards, *i.e. towards* Gore Point. It is therefore probable that the present Holme marsh, *i.e.* the Lavender marsh, has developed since the Enclosure Maps of about 1858 or even a little later. This gives sufficient time, judging by the known rate of accretion and marsh development at Scolt and elsewhere.[2] In 1931 a storm breached this new bank, and built the large shingle fan now lying over part of Holme marsh.

A still earlier map (1609) of Holme by Heywood existed, but I have been unable to find the original. A copy of this map—correct so far as known—is in the possession of Mr. T. Nelson of Holme. It is a large-scale plan giving full details of ownership of land and property, and it also extends to the coast. The coastal outline is rather difficult to interpret. The map includes an area rather farther to the east than do the Enclosure Maps, but it is possible to relate them in a general way. Unfortunately it is not at all easy to obtain clear boundaries between natural and reclaimed marsh and dunes and beach on the older map. Two pairs of double lines mark what appear to be approximate L.W.M. and H.W.M. The precise significance of these double lines is not clear. Gore Point is in the same general position and also stage of development as it is on the Enclosure Maps, and the meanderings of Broad Water and associated creeks are somewhat similar. Again, as on the Enclosure Maps, in the eastern part of the stretch of coast shown there is marked a line of "Hills and Sands" outside Broad Water. These correspond quite well with their modern representatives in general position, though many minor modifications have presumably taken place subsequent to the date of this map. Allowing however for the natural difficulty in interpreting confusing features on an old map, and also for a certain amount of approximation in coastal outline, there is a general agreement between this and the later maps which were made in connection with the enclosing of Holme Marsh.

In short, the stretch of shore from Hunstanton cliffs to the present wall shutting off the reclaimed Holme marshes from the natural marsh at Thornham seems to have been formed under conditions generally similar to those now prevailing at Thornham, Scolt, and other places along the north Norfolk shoreline. Off-shore bars have formed which in some cases have become stabilized and lengthened by beach-drifting,[3] so that adjacent bars have some-

[1] See also map of present features of the coast (1934) by R. F. Peel.

[2] See 'Scolt Head Island' (Heffer, 1934), papers by V. J. Chapman and J. A. Steers, and *Geol. Mag.*, October 1935, *re* accretion rates in Norfolk Marshes.

[3] The writer, for reasons discussed elsewhere (see *e.g. Geogr. J.*, June 1934), does not agree with Marsh in suggesting that shingle banks are due to current action.

times united. These have suffered modifications from time to time—have been broken through and later "healed up." Along Hunstanton Golf Links the present tendency for new parallel dune ridges to form illustrates this point, as also does the formation of Thornham West Island and the new, low shingle and sand ridges near it.[1]

The Thornham Foreshore

Between the sea-wall surrounding the reclaimed marshes at Titchwell and the dunes and wall enclosing those at Holme is a space about 1 1/2 miles from east to west of natural foreshore.

This area is interesting from several points of view. In the first place it shows the development of small sand and shingle bars and dunes which shut off quiet stretches from the sea, thus allowing the formation of natural salt marsh. Secondly, the features existing off Thornham are usually structures subject to rapid changes in relatively short periods. Thirdly, some of these features illustrate what might well have been an early phase in the growth of Scolt Head Island, about 2 miles to the eastward.

The development of this stretch of foreshore closely resembles that of Wells. There is an abundance of sand on the foreshore, and sand flats, sometimes exposed at low water, occur farther seaward. The present distance between high and low water marks at spring tides off the outer dunes is almost half a mile. These sand flats are merely part of the extensive series which runs from the Wash to Cley. At Thornham offshore bars have been, and are being, built on these flats.[2] Dunes later grew on these bars around plants, first of *Agropyrum junceum* and later of *Psamma arenaria*. This is similar to other parts of this coast. Thornham and Wells are in fact creek harbours.[3]

The early details of the development of Thornham foreshore are lost. The features which can be seen to-day are probably similar to older structures in all essentials, but with the reclamations at Titchwell on the east and Holme on the west it follows that conditions would be materially altered, because there is now only a relatively short stretch of natural shoreline.

[1] No details regarding salt-marsh vegetation and ecology have been given in this section because (*a*) the natural salt marshes have been fully described in the paper by A. S. Marsh already mentioned, and (*b*) because as so much of the area is reclaimed marshland, an ecological description would be out of place in this paper. Hence, only the general development of this part of the coast has been described, whereas brief ecological notes are given in the Thornham section, which has so far not been described in any publication.

[2] The occurrence of an extensive submerged forest off-shore from Brancaster to Old Hunstanton testifies to a comparatively recent downward movement of the land in relation to sea-level. This forest is the equivalent to the middle forest bed described by H. and M. E. Godwin in 'Scolt Head Island.' Whilst noticing the occurrence of this forest, it is unnecessary to discuss its origin in this place, as the recent vertical movements in this coast have not yet been fully worked out. Tentatively I am of the opinion that the shallow water on the sand flats is in itself sufficient to cause waves to break well away from the mainland proper, and so to construct off-shore bars. In fact there is probably no compelling reason to assume any change in sea-level to account for the shore features here discussed.

[3] For further details regarding the formation and subsequent development of Wells Harbour see Appendix to Second Report of the Commissioners appointed to inquire into Tidal Harbours, 1846.

Erosion is at present taking place between Brancaster Golf Club House and Titchwell, but running westwards from the copse at the Thornham end of Titchwell sea-wall is an interesting development of new dunes. The last edition of the Ordnance Survey (1907) marks a small channel running from the marsh to the foreshore about a quarter of a mile west of the copse. To-day a similar break still exists, but new dune hillocks are rapidly forming on the Titchwell side of it, and so prolonging the line of dunes from Brancaster and Titchwell.

West of this break the same map shows a continuous ridge, rather more than three-quarters of a mile in length, extending to Thornham harbour. This ridge has suffered a good deal of alteration. There are, in fact, now two separate ridges: the one nearer Titchwell and bordering on the west side of the creek mentioned above is interesting. Many of the older dunes on it are in the grey dune stage, and near its western end it shows obvious signs of fairly recent erosion (1934). But along the eastern part of its seaward side new dune is rapidly forming and the line of junction between what was once an eroded dune face and the new dune with *Agropyrum junceum* is clearly seen both in the colour of the sand and in the nature of the vegetation. At its western end the new dune on the seaward side is only gradually covering the old dune, and much of the eroded slope can still be seen. The extreme western end of the ridge is mainly bare shingle with a few small dunes growing on it in a way very similar to the dunes beginning to form on the Far Point at Scolt Head Island. This shingle end shows the usual recurved features.

Westwards from this point is a bare, flat shingle spread, about a quarter of a mile wide from east to west. Seawards the shingle gradually gives place to the sand of the lower part of the beach. The main drainage channel of Thornham marshes runs alongside the inner edge of this shingle, at the western end of which is another small island, a remnant of the once nearly continuous ridge of the first edition of the 6-inch Ordnance Map (1892). This island is being eroded (1934, 1935), and its seaward side is well cliffed. The vegetation resembles that of the island, described above, lying eastwards of it. At the present time the two ends of this island are curved sharply back to the marsh channel.[1]

The harbour channel finds its way to the sea through extensive sand flats. The deepest part of the channel is approximately in the line of the two islands on either side of it. Seawards it shallows and it is impossible to float even a small rowing-boat in it for about three hours on either side of low water.

West of the channel and east of the dunes enclosing Broad Water and the Holme reclamations an entirely new island has formed in the last six or seven years. This island is semicircular in form and curls landwards at its extremities. It is a shingle and sand ridge which has been built by wave action at or near the high water mark of spring tides on the main beach. It is similar in structure to the islands already described, but as it is much newer and in process of development it presents interesting problems. Dunes have already begun to form on it, especially near its ends. A few smaller dunes originate in its mid-part, but some of them are later destroyed by storm waves at high spring tides. There is one lateral ridge running landwards from the island, but it is shorter

[1] The in-curving of the western of these two ends was intensified during the high spring tides and strong winds of September 1935.

and flatter than those at Scolt. The sand flats within the ridge are gradually receiving a thin coat of mud, and masses of seaweed left on these flats are beginning to afford shelter for the growth of plants, such as *Salicornia* spp.

The vegetation of this island is interesting, and typical of such a habitat. Fifteen species were collected by Dr. V. J. Chapman in 1934. The future development of the island should be watched with care.

This island and neighbouring features were first mapped by Mr. B. C. Gibbs in 1934, and re-mapped by Mr. O. H. K. Spate in 1935. During that time slight changes had taken place. The western end of the island had suffered some loss, and there were minor changes in the spits at either end.

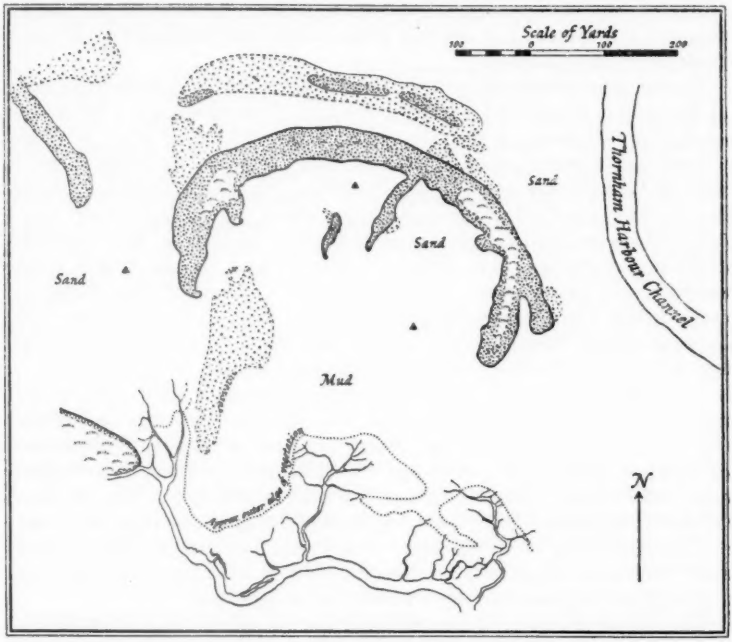


Fig. 3. Thornham West Island, after surveys by B. C. Gibbs (1934) and O. H. K. Spate (1935)

Small differences were noticed in the incipient dunes on the ridge: as these have not been fully stabilized by vegetation, alterations in form due to strong winds and occasional storms are only to be expected. Furthermore cattle are allowed on the foreshore and they trample down and help to alter and destroy new dunes. The 1935 mapping also suggested a slight encroachment of the sea along all the weather side of the island, but it is difficult to say how far this is genuine, because the shingle-sand boundary varies with the weather conditions, and is always difficult to demarcate. Probably there has been some erosion, but how much cannot be exactly estimated. Another small point worth noticing is that there is now (July 1935) a small, low shingle-sand-shell ridge growing up in front of this island. It is very low and not by any means

a striking feature, but it affords a little protection to the island, and is of much the same nature, though on a lesser scale, as another ridge, composed mainly of sand with but little shingle, which is being formed west of it and partly in front of Holme dunes. It is too early to do more than record the fact of the existence of this long ridge as it is overtopped by spring tides and liable to be shifted, even if not washed away, by storms.[1] In 1935 the eastern end of this ridge was more pronounced, but had definitely been moved inland a few feet from its position in 1934, and a channel between it and the western Thornham island is developing, which will probably limit the westward growth of that island. If new surveys are made of this area at frequent intervals their results will be of value in that they will indicate the nature and rapidity of the changes to which it is subject, and also may serve to show the probable way in which Scolt Head Island formed.

Certain field observations suggest that the travel of beach material along all this stretch of shore is generally to the west. The disposition of the shingle on the sand (the ends of the ridges near Titchwell, etc., all point west) and the process of formation of new dunes, which arise mainly on these ridges, point to the same conclusion. Very local travel, as for example on what may be called the foreshore of the new western island, would depend very much on (*a*) winds and waves at any particular time, and still more (*b*) on what part of the shore of this island the observations were made. Beach material on the eastern curve would travel landwards, whereas material farther round the curve would move westwards and landwards. This is, in miniature, what happens at Scolt Head Island. The main movement of material is to the west, but at Burnham Harbour it is eastwards and landwards.

The marshlands within all this stretch of foreshore show development normal to the Norfolk coast. Generally the marshes decrease in age towards the west. Near Titchwell wall is old high marsh, often with much blown sand on it near the dunes. The main plants are *Plantago maritima*, *Armeria maritima*, and *Limonium vulgare*. Farther west these gradually give place to *Aster*, *Glyceria*, and *Salicornia* spp., the dominant plants in front of the old granary at Thornham. Higher marsh plants are found in the inner parts of the marsh near Thornham village. Within the new western island the bare sand flats are only just beginning to receive a covering of vegetation.

The marsh has spread outwards from the old shoreline (*i.e.* the present inner edge of the saltings). Near the sea-wall running between Thornham Harbour and sluice as far as Holme dunes such plants as *Obione portulacoides*, *Limonium vulgare*, and *Plantago maritima* are found. But if a transect is made seawards from the inner edge, the vegetation will be seen gradually to change until *Aster tripolium*, *Salicornia* spp., and *Suaeda maritima* var. *flexilis* with *Glyceria maritima* become dominant. The outer edge of the vegetation is irregular, and scattered plants of the above-named species are spreading on the bare sand flat and gradually converting it into a true marsh.

A parallel development is seen in the creek system. The best-marked creeks are all in the true marsh. Pans are common in the older marshes. Between the sluice and the western island creeks are found in the marsh near the sea-wall, but they are lengthening seawards by a kind of headward erosion. This is

[1] This ridge is indicated on Fig. 2 and Folding Map.

explained mainly by the fact that at high spring tides the sand flats within the island are covered, and much of this water drains back, *i.e.* landwards, into the existing creeks, so causing them to extend seawards. The slope of the ground determining this direction of flow is due in the first place to wave action, which has built the islands and ridges to which frequent reference has been made. The waves, as well as constructing these ridges, have so graded the outer beach that it slopes very gradually upwards (neglecting the shallow sand ridges and gullies found on it) to a line roughly coincident with that on which the islands stand, and from this line slopes slightly downwards again in the direction of the mainland. The water therefore behind the western island, after the top of the tide has drained seawards, runs either directly eastwards to the main channel, or to the creeks in the marshes in rear. The gradual extension of this marsh over the sand flat is a matter worth careful observation.

As far as can be ascertained from a short series of observations, the tidal currents run parallel with the shore-line close inshore, and the direction of flow is westwards up to an hour or so before high water. Then the current reverses and flows to the eastward. This is similar to what happens off Scolt Head. But the very shallow water off Thornham can easily be affected by the wind, and the few observations made seem to suggest that with a fresh wind from the eastward the change to the eastward-flowing current may be delayed. In any case there is no need to suppose that the currents have had any direct effect in building the ridges and islands. These, like Scolt, are the product of wave action, and the general environment of the whole area renders it more than probable that the conditions favouring a westward drift of beach material at Scolt Head Island prevail at Thornham also.

Titchwell

Numerous inquiries and inspection of all the available maps of the parishes of Thornham and Titchwell have failed in helping materially to trace the historical evolution of the foreshores of these two places. In 1934 Mr. R. F. Peel, at the writer's request, overmapped on the 6-inch Ordnance Survey maps the main features of the foreshore and marshes from Hunstanton to Brancaster (see Folding Map). It will be seen that there are old shingle ridges in the eastern Thornham marshes and that they are continued to the reclaimed marshes at Titchwell. As far as can be seen from natural sections and their general appearance on the ground and map, these ridges are in every way similar to the existing coast ridges, and were presumably formed in much the same way, *i.e.* as off-shore bars at an earlier period. It will also be noted that there is a practically continuous line of creek from Thornham harbour channel through Thornham marshes and Titchwell marshes to Brancaster, where it practically joins Mow Creek. I have been unable to find any historical data helpful in reconstructing the evolution of these creeks and marshes, but it may be suggested that at one time there was a continuous natural channel along this line from Thornham to Brancaster Staithe; a channel corresponding very closely with Broad Water to the west and Norton Creek to the east. Granting this we should have an outer sandy and shingly foreshore with dunes here and there (represented by the old ridges now incorporated in the reclaimed marsh at Titchwell and still "natural" in Thornham East marshes) on the seaward side of this channel forming the rough counterpart of Scolt Head

Island. This is entirely consistent with what is known elsewhere of this stretch of coast. The present conformation is merely, in this case, due to artificial alteration, *i.e.* building of sea-walls and so on, which rest partly on ridges formed by wave action and exterior to those mentioned above.[1] The precise dates of the construction of these sea-walls are apparently lost: those around Titchwell marsh seem to have been built in the seventeenth century. A comparison of the two sections of the Folding Map shows the general nature of the changes of the Thornham foreshore. The changes in the outlet of Thornham harbour channel are interesting: they are similar to the fluctuations in the channels from Brancaster Staithe, Burnham Harbour, and Blakeney.[2]

In short, the changes which have taken place in recent historical times along the whole stretch of shore from Hunstanton to Brancaster are consistent but not simple. Occasional offshore bars have been formed; these may or may not have joined up. Channels have shifted their courses. Storms have breached the bars and new ones have formed. Marshes have grown within the bars, and have developed, as inside Thornham West Island to-day, from the mainland outwards. Sea-walls have been built and other artificial alterations made. But all these changes are entirely those which would be expected on a shallow flat foreshore such as this. They are, in a general way, similar to the causes which have produced Scolt Head Island, though west of that island there is less shingle, and conditions off Holme, Thornham, and Titchwell have not been such as to produce a large and composite structure as Scolt Head Island.

[1] In a general way—no exact comparisons are possible—the present shore-line of this area corresponds to Scolt Head Island. The ridges now within the marshes correspond to the ridges of Brancaster Golf Course and those south of Norton Creek (see *Geogr. J.*, 1934). The channel, referred to above, thus corresponds more closely with Trowland Creek than with Norton Creek.

[2] An interesting note concerning Titchwell in the fourth decade of the seventeenth century is quoted in *East Anglian Notes and Queries*, N.S. vi., 1895–96, and also in an unpublished proof (preserved in Norwich Library) by W. Rye, and intended for the Victoria County History. The note reads as follows:

"I (*i.e.* Sir Nicholas L'Estrange) remember most of those Marshes lying between Tichwell town and the land to have been fresh pasture and a great water called Tichell Ea with a strong Reed land and a good lake for fish especially Fresh water Butts, and a stronghold for Otters, but by one nights high tide and a strong winter A° 168 (?) all the great sandhills called Meales were entirely Levels, and the sea wrought itself a channel out of the shore near Brancaster Bank tis likely now to continue a Salt Marsh. For the property being [in the hands of Magdalen College], and the Fellows contenting themselves with the old rent—neither the Principal Tenant under them nor his underservants will care to contribute towards the charges of Imbanking them a fresh. Brancaster Bank being by this means exposed to the strong west winds suffers very much and t'will be great expenses to them to keep in repair."

In the absence of documents and maps I am unable to say precisely how this information can be used. It does however illustrate the kind of thing which happened, and can, in some ways, be paralleled by the breaking through and flooding of the relatively small marshes just east of the Club House on Brancaster Links a few years ago.

Incidentally, it may be mentioned that the Dutchman, Van Hasedunck, apparently carried out reclamation schemes at Thornham (on the Titchwell boundary, so far as I can say) and Holme in 1642–43. Details are missing.

(N.B.—Much of the Sea Buckthorn (*Hippophäe rhamnoides*) which is common off Thornham was planted by the late Mr. V. Ames a few years ago. This fact helps to explain its present distribution and its absence from Scolt Head Island up to 1934, when a single plant was seen by the watcher. This plant is now (1935), on the authority of Dr. Chapman, a healthy bush.)

APPENDIX

Admiralty Chart No. 108, the Wash, affords some interesting data of tidal streams near Gore Point. The actual place of observation is lat. 52° 57′ N.; long. 0° 28′ E., a point about 1 mile north-west of Hunstanton Pier, or 2½ miles south-west of Gore Point. The tidal streams here will not be exactly the same as those affecting the foreshore, but the place is near enough to indicate their general nature.

For reasons demonstrated elsewhere[1] it must be assumed that wind-wave action causing beach-drifting is the main cause leading to the building of shingle bars and similar features on this coast. At the point referred to above, the direction of tidal flow, referred to the time of high water at Hunstanton Pier, is as shown in the table:

DIRECTION OF TIDAL FLOW AT POINT L, ADMIRALTY CHART, THE WASH: LAT. 52° 57′ N., LONG. 0° 28′ E.

(All bearings are true)

Hours before *H.W. at Hunstanton*	*Direction to which streams flow*	*Knots* (*Springs and Neaps*)
6½	208°	*Spring* 0·4 *Neap* 0·2
5½	204°	0·7 0·4
4½	198°	0·8 0·4
3½	194°	1·3 0·7
2½	194°	1·5 0·7
1½	201°	0·8 0·4
½	19°	0·4 0·2
Hours after *H.W. at Hunstanton*		
½	26°	1·5 0·7
1½	23°	2·0 1·0
2½	21°	1·8 0·9
3½	17°	1·0 0·5
4½	15°	0·4 0·2

[1] 'Scolt Head Island' (Heffer, 1934), and *Geogr. J.*, June 1934.

In general, this means that the water is flowing some few degrees west of south up to about 1 ½ hours before high water; and then from about 1 ½ hours before high water at Hunstanton for about 6 hours it reverses and flows in a direction a few degrees east of north. It could be inferred from this that as the shingle ridges beyond Hunstanton and west of Holme and Thornham conform in a general way with these directions they are therefore due to this cause. But it is important to stress the fact that only at springs is the beach shingle really worked on by the sea and also that by the time the waves have broken the tidal currents no longer act. Further, it is only for a very short time, relatively, near high water that the shingle is reached by the sea, and, as seen in the table, the current direction changes a little before high water at Hunstanton. Hence we can neglect the idea that tidal currents have any effective control of the shingle banks on the foreshore.

Wind directions here may be taken as generally the same as those quoted in 'Scolt Head Island,' for the Cromer Knoll Lightship. The prevalence of westerly winds is clearly shown as well as the lesser number but greater effectiveness of winds from between north and east.[1] These north-easterly winds are the effective winds as far as beach-drifting is concerned all along the Norfolk coast from Blakeney to Gore Point, and their action in causing waves, and especially swells, to come in from the quarter between north and east accounts for the growth of Scolt Head Island, the features off Thornham, and the ridges between Thornham and Holme. But at Gore Point the trend of the coast changes. Winds from north and north-east should lead to a certain amount of beach-drifting into the Wash, but north-westerly to south-westerly winds now have more open water over which to work and presumably to set up some beach-drifting to—as an average direction—the north-east. Hence, around Old Hunstanton and Holme irregularities are to be expected, and it is in this way that the rather curious arrangement of shingle ridges and the past changes due to storms from west to north-west have probably been brought about, but there is ample scope for much detailed field work in this area before anything decisive can be written on the matter.

[1] The Great Ouse Catchment Board have made a long series of wind observations at Lynn Well lightship. The main results are: (1) The prevailing wind throughout the year is south-west, except during the second quarter, when it is east; (2) the prevailing strength of the wind is 3—*i.e.* a gentle breeze, 12 m.p.h.; (3) strong gales usually from the west-north-west occur about twice a year at any season.

I am indebted to Mr. O. Borer for permission to reproduce these conclusions, which were obtained for me by Mr. W. P. Spalding.

STONE STRIPES

THOMAS HAY

MANY phenomena, which are reported as vigorous frost manifestations in Arctic and Sub-Arctic regions, occur on the highest lands of the north of England and Scotland in a diminished and weakened condition. Of these various phenomena none is more interesting and intriguing than the Stone Stripes which have been found in Scotland and on the fells of the Lake District. Dr. S. E. Hollingworth first called my attention to these arrangements of stones and his recent paper on "Some Solifluction Phenomena in the Northern Part of the Lake District" (*Proceedings of the Geologists' Association*, Part 2, 1934) has given a great additional interest to the subject.

The observations given in this short paper are really a continuation of some of the work described by Dr. Hollingworth, and it is hoped that they may not be devoid of interest. The subject, which often comes beneath the notice of the geographer, is one to which I have been able to give some little attention during the last few years. Quite recently Dr. A. Raistrick has told me that he has found these stripes in many places in the Lake District as well as on the Pennines.

After a frost it is a matter of common observation that the ground is often heaved upwards. If a piece of the frozen ground be turned over and examined it will be found that the heaving has been performed by little bundles of prismatic ice needles. Högbom, whose paper, "Über die geologische Bedeutung des Frostes," is a perfect mine of careful observation, refers to these ice prisms as "Pipkrake" or "Kammeis." No generally accepted word seems to exist in English for this kind of ice, but an American author, Stephen Taber, has called them "Needle Ice," and it seems difficult to suggest a better name for these "frost columns of ice," or "columnar ice needles," as they have been variously called. Mr. Taber's paper on "Frost Heaving" (*Journal of Geology*, vol. XXXVII, No. 5) is very instructive, but it is entirely devoted to a laboratory investigation of the problems connected with frost heaving.

The natural frost heaving of our paths or any other suitable surface in winter is caused by this needle ice, and a simple experiment will show its method of growth. During frosty weather last January a bare path of gravelly clay was visited, and it was found that a raised carpet of gravel on needle ice stood above the original surface looking so exactly like the previous surface as to be indistinguishable from it by the eye alone. A patch of this needle ice and its surface of almost continuous raised pebbles was scraped off over an extent of about 1 square foot. The frost continued and the same place was visited next day, when it was found that:

(1) Over the cleared part a fresh crop of needle ice had arisen bearing a fresh surface of raised matter.

(2) Over the uncleared part, the crystals had doubled in length and between the two stages of growth there was a surface of raised matter parallel to the original surface of the ground (Fig. 1).

This shows that the needle ice feeds on water supplied from below. In fact this water comes up through molecular cohesion. Secondly we see that little

stages of growth in the prismatic ice, marked out by more or less continuous included matter, correspond to spells of frost action.

A word or two more about the needle ice may be given. The prisms grow up at right angles to the exposed surface of the ground. On the flat they would be vertical but on a slope they would be inclined at the corresponding complementary angle. They are continuous from end to end and are arranged in bundles, but the bundles may be quite separate from adjacent bundles. The intervening space is of course filled with air. The apparent increase or heaving in the surface is not caused by the increase in volume of the frozen water. It is far in excess of that owing to the discontinuous nature laterally of the needle ice causing the elevation.

This possibly tedious introduction is absolutely necessary to the explanation of the stone stripes which will now occupy our attention. These stripes consist of alternate lines of larger and smaller stones lying parallel to each other and running down the principal slope of bare patches of stony ground on some parts of the Lakeland fells. They have been well described and drawn in Dr. Hollingworth's paper already referred to, but for the benefit of those who have not got ready access to that, it may be added that the distance from one stripe to the next similar stripe is usually somewhere about 13 or 15 inches.

The following observations have been made at different times during a period of over three years. Visits were made at seasons that afforded the opportunity of examining the stripes in winter as well as in summer and especially during and just after a period of frost.

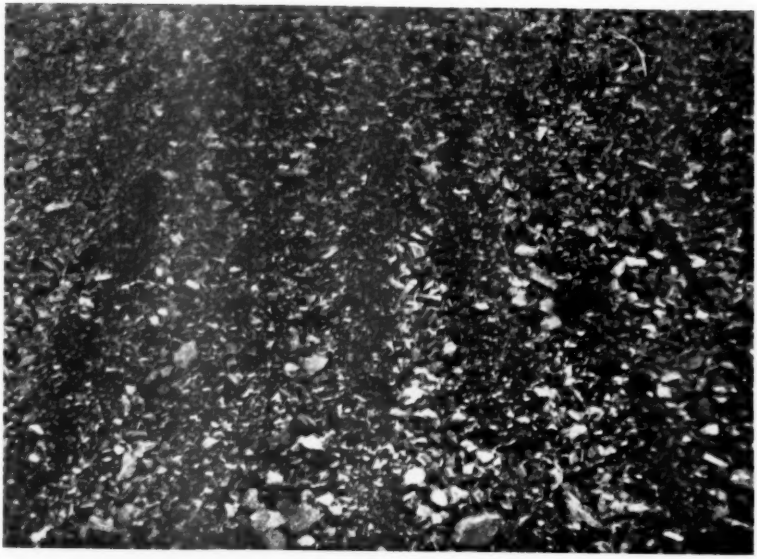
In summer the general level of the coarse stripes and of the fine stripes is the same, but after a frost of any intensity the fine stripes stand higher than the coarse stripes. During a frost the coarse stripes are quite loose and easily moved to a depth of some inches, but the intermediate parts are hard and bound together by frost. After a thaw which has not had time to penetrate deeply it is found that the fine stripes are a mass of thick sludge but the coarse stripes are not.

The stripes appear to be solely a surface phenomenon because on digging down into the ground one finds in descending order: (1) Surface stones; (2) dark brown or grey top soil with some stones but with a continuous matrix of soily stuff; (3) underlying yellow stony matter at a depth of about 15 inches. Where the stripes are well developed, if the loose incoherent surface matter is gently and carefully removed by the fingers, it is found that the coherent clayey middle layer is arranged in troughs and rounded ridges running down the principal slope. The coarse stone stripes lie in the troughs.

By digging into the turf separating two patches where the stripes are developed, it is found that there are no stripes buried beneath the turf. The stripes are a present-day phenomenon and not a fossil one, although I believe that fossil examples also exist in some places. The stripes occur on slopes where the turf has been disintegrated and wholly or partially destroyed under the action of frost and solifluction. The stripes never begin at the top of such exposed places. They need a distance in which to develop. The turf has been a deterrent to their development (Fig. 2).

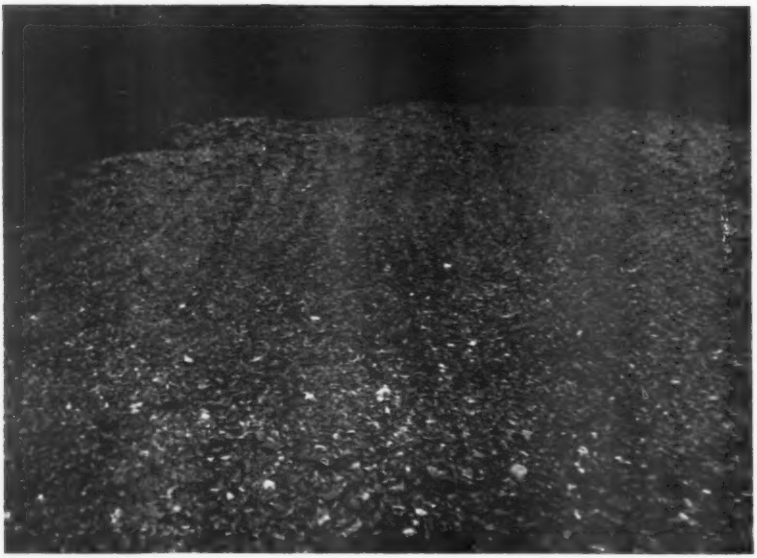
On a frosty sunny day of March this year (1935) some observations were

Needle Ice: a small cliff of prismatic ice in two stories



Alternate coarse and fine stripes (Helvellyn)

Stone stripes on Helvellyn



Tongue-shaped expanse of gravelly surface (Helvellyn)

made on the Helvellyn ridge. There had been a week of the same kind of weather during which the tops must have been frozen hard every night with a thin top thaw in suitable places during the day. Even hummocks of disintegrating grass were quite hard with a thin surface softness. There was found to be considerable thaw on the surface where the westward-facing Helvellyn stripes are developed and about 3 inches of slushy matter lay over the fine stripe lines, while stones lay as usual over the coarse stripes. The thawed top was cleared away over two fine stripes and the intervening coarse stripe. Then the frozen ground was cut into until the unfrozen ground was revealed as a flat slope $5\frac{1}{4}$ inches below the top surface. Directly above the unfrozen ground there was a wonderful layer of needle ice $2\frac{1}{4}$ inches thick with several stories or layers parallel to the surface and a fair amount of included small matter from the soil. The fine stripes were projecting noticeably above the coarse stripes. One bigger stone, $2\frac{1}{4}'' \times 1\frac{1}{4}'' \times 1''$, was in the needle ice,

Fig. 1

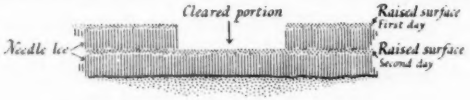


Fig. 2

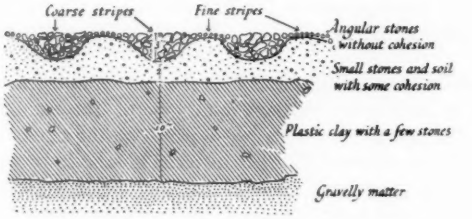
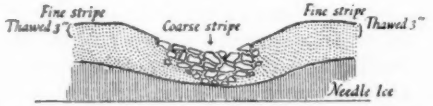


Fig. 3



i.e. frozen in and raised up quite clear of the unfrozen ground underneath. A biggish piece of the frozen matter was turned over, and this showed the hollow left by the elevation of the stone. If this had been left in position it would not have been able to sink back into the original position because small matter would have slipped or sunk or melted in previously. Clearly then all the matter in the fine stripes is subject to a great deal of frost heaving at each alternation of frost and thaw, but the coarse stripes do not get so much of this movement.

In July a careful examination was made of the nature of the surface separating the loose incoherent matter on the top from the coherent part underneath. A breadth was selected containing five fine stripes and the four intervening hollows containing the four coarse stripes. This breadth was very carefully cleared of all loose incoherent surface matter and the system of troughs or hollows separating the ridges was revealed. These troughs or hollows were now traced up the slope by making eight other similar clearances of the loose surface matter. It was then found in the top clearance just below the edge of

the disintegrating turf that the coherent surface showed a plane unvaried top without corrugation. The next lower clearance showed the cohesive ground slightly ridging itself with tiny hollows running downhill, but not regularly and not even straight. There were traces of five tiny depressions. The lower clearances showed variations in the development and in the spacing of the depressions. But the general result was that the depressions became emphasized as they descended the slope, they became more regular in direction and in spacing. In the last clearance, *i.e.* the lowest one, there were four well-developed and regular hollows, and it was here only that the stone stripes were a noticeable feature.

I suggest the following explanation. The stripes are caused by the sorting upwards of the stones which subsequently get arranged into parallel lines. The stones in this upward journey ultimately pass through the boundary surface between the coherent and the incoherent layers. The frost heaving which causes this upward sorting starts irregular corrugations in the top of the coherent layer. Some of these by increasing the surface of discharge of the stones prove beneficial to the process while some are suppressed. Gradually those corrugations or hollows suitable to the exact place become stabilized, and then only do we get the stripes showing themselves. As soon as the hill and hollow arrangement is formed, the bigger stones during frost-heaving naturally move into the hollows and the finer materials occupy the intervening spaces.

In order to keep the discussion as clear as possible it has been necessary to omit some details, but perhaps it may be of interest to mention two other points. The spacing of the stripes depends on the size of the material and on the slope of the ground. Larger material gives rise to wider-spaced stripes. On Helvellyn, where the material is small, the distance from one line to the next similar one is about 13 inches. On Low Man, where the material is larger, the usual spacing is 17 inches. On Stang, where the blocks are as large as 1 foot, the spacing may even be 2 feet 6 inches.

The lines are closer together on a steeper slope. The slope on Helvellyn is about 1 in $7\frac{1}{2}$. On Low Man a change of slope occurs in the middle of the striped area, and here it can be seen that in one or two cases there is a coalescence of two lines at this point where the slope changes from steep to less steep. Thus on the lower, less steep slope there are fewer lines occupying the same breadth of ground as on the steeper slope.

LAKE BOSUMTWI, ASHANTI

HERBERT P. T. ROHLEDER

THE following paper was written during six months' reconnaissance and prospecting work in the immediate vicinity of Lake Bosumtwi, which lies approximately 20 miles south-east of Kumasi, the capital of Ashanti, at an altitude of approximately 350 feet above sea-level. The shape is roughly circular with an average diameter of 5 miles at the lake surface and $6^{1}/_{2}$ miles at the caldera rim which surrounds the lake depression. The inner slopes of the latter, rising up to 1200 feet above lake-level, are very steep, whereas the outer slopes are gentle and at times scarcely recognizable when approaching the lake from the neighbouring country.

As the name derives from *obosom* meaning God and *twe* the name of the lake spirit, the spelling Bosomtwe appears to be more correct than the usual Bosomtwi.[1] The lake is an object of native superstition.

Any effort to solve the problem of origin of this mysterious lake is faced by exceptional obstacles. The lake is still within the dense forest belt of Ashanti, accessible only along native paths and hunters' tracks, which are quite numerous, and occasionally by a stream-bed. If one wishes to examine beyond this, one is forced to cut a way through the thick bush, and even then the soil is covered with decaying vegetation and undergrowth. The slopes of the depression are so steep that after a heavy rainfall it is neither possible to climb down nor up, and unfortunately the lake depression is known to be a locality of exceptionally frequent and heavy rainfall.

The geology and character of the problem are extremely complicated. With the exception of practically recent clays and very scanty, relatively young agglomerates, the only rocks in the vicinity are of Birrimian (precambrian) age. But these comprise a whole petrological collection: sedimentary, metamorphic and igneous rocks; of the latter intrusive, hypabyssal and extrusive, acid, intermediate and basic, effusive and explosive types. Of the breccias some are possibly of tectonic origin. But what of all this is actually connected with the origin of the lake?

The whole earth's history lies between. Rocks of Birrimian age can look as fresh as if they were recent, whereas nearly all types of quite young rocks may under the highly tropical conditions of West Africa change soon into lateritic or bauxitic alteration products.

Previous work on the subject is scanty. In spite of very little concrete evidence, three theories have been put forward: the meteoric theory; origin of the basin through subsidence; volcanic origin.

The meteorite theory originates from Malcolm Maclaren (1), and since the date of his publication (1931) meteoric craters have become known from all parts of the world (2). At one time two points seemed strongly in favour of this theory: the apparent absence of any young volcanic material or other geological features explaining this sudden deep depression, and the fact that this lake is an isolated occurrence incomparable with any other geological

[1] Since the P.C.G.N. prefers Bosumtwi, this form of the name has been adopted in accordance with the practice of the *Journal*.—Ed. *G.J.*

feature within the Gold Coast. Against the theory, although by no means disproving it, were the vast size and the absence of any meteoric material. The latter is explained by Maclaren as probably because the meteorite was stony.

According to Maclaren no reliable meteorite fragments were ever found by him or others at or near the lake. Although some fifty years ago meteorite finds were reported from Anamuko on the south-west of the lake, the author could not get any positive information about these finds from the Chief and elderly natives living in Anamuko and neighbourhood. It would be of importance to know whether these reports originated from Europeans or natives; in the latter case they would be meaningless.

Magnetic observations for deviations in declination, inclination, and intensity, made by Maclaren with a prismatic compass and dip compass showed no aberrations as regards declination; the dip compass however showed irregularities in inclination and magnetic intensity, "compatible with the existence of a magnetic ore body in the lake north-east and south-east of the village of Isasi on the south-west shore. Observations, carried from Dampa in the south-east corner of the lake to Ajuafo in the north-west corner, indicated a zero point." "A drag of the compass needle" up to 12° towards the lake was recently (1934) confirmed by Mr. J. E. Gresham Williams, an Englishman in charge of the underground operations at Esikim, 2 miles east-south-east of Lake Bosumtwi.

Maclaren himself places very little reliance on these few observations, and indeed if these deviations were proved to exist they would stand much more against than in favour of his meteoric theory. So far Maclaren had to assume a stony meteorite, which is non-magnetic. Immediately the question would arise: Where are the remains of this vast body of meteoric iron which caused a hollow of nearly 20 square miles surface and the geomorphological appearance of which proves comparatively young age? Apart from this the existence of magnetic anomalies would by no means necessitate the existence of meteoric iron, as will be discussed later.

As a very dubious criterion for the meteoric origin Maclaren makes the statement: "The depth of the (Bosumtwi) crater from the lowest portion of the rim to the bed (?) of the lake is 1150 feet. It is probably no coincidence that this is exactly the depth to the solid rock given for the famous meteor crater in Arizona." But surely if these figures happen to be equal, it is nothing else but pure coincidence, especially as the Arizona Crater has only a diameter of less than 1 mile as compared with the 5 miles diameter of Lake Bosumtwi.

Equally doubtful is Maclaren's statement, incidentally also made by Sir Albert Kitson, that " pure gas eruptions have never been recorded outside already existing volcanic areas." Such are known from many parts of the world. Besides, since then scanty agglomerates of recent age have been found close to the lake, showing that Lake Bosumtwi is not entirely due to a pure gas eruption.

Very little material could be obtained to support the theory of basin subsidence, controlled by intersecting faults or fault pairs. The theory was tentatively suggested by the Gold Coast Geological Survey years ago (4). Maclaren rightly points out the obvious youth of the depression, which would necessitate young lines of fracture within the old Birrimian rocks in the

vicinity, but such have so far neither been located by previous workers nor by the author. Certain breccias were noted by the Geological Survey and also by the author. The Survey states that "some of them are undoubtedly fault breccias" (4), but the author is inclined to interpret them as volcano-tectonic, as will be explained later on.

Besides, if the Bosumtwi depression was controlled by lines of weakness, one should expect more than one isolated lake and the circular shape is definitely against this theory. Lakes bounded by fault lines, especially at the bottom of rift valleys, show a pronounced elongation, as is best demonstrated by the string of lenticular-shaped lakes in East Africa and the Jordan valley, Palestine.

Subsidence due to solution, *i.e.* dolina origin, is quite out of the question, owing to the insolubility of the rocks, as Maclaren has rightly pointed out.

Thus there remains only the volcanic theory. Sir Albert Kitson, in 1916, was the first to point out the similarity of Lake Bosumtwi to a volcanic

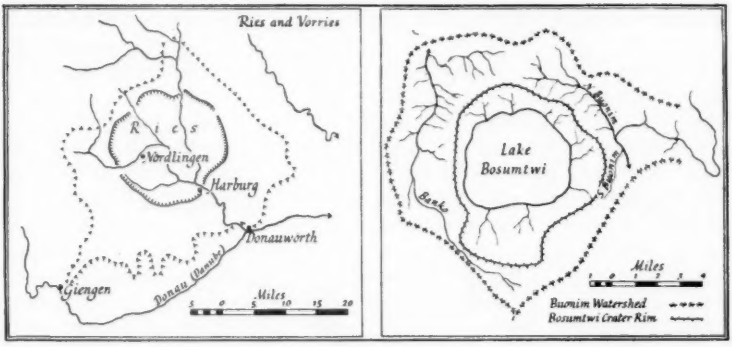


Fig. 1

explosion crater, but he regarded it as "pseudovolcanic" and due to subsidence. The actual volcanic origin was then suggested by the Gold Coast Geological Survey after the convincing finds of explosive material by D. P. McGregor (4).

My own theory of origin of the lake depression incorporates to a certain extent ideas which have vaguely been suggested in the theory of subsidence. The lake was visited by me on six occasions, each comprising several days' field work. Besides examining the geology exposed along all native paths and stream-beds, where approachable, I cut 35,700 feet of traverse lines through the dense bush, and five potholes were dug in the country adjoining the south-east portion of the lake; the latter, although reaching Birrimian bedrock, in no instance revealed the expected volcanic material, but by this negative evidence proved that at those particular parts of the caldera rim no fragmentary volcanic material is to be found overlying the Birrimian schists and phyllites.

In my opinion the key to the correct interpretation of the Bosumtwi depression is to be found in the Ries of Nördlingen, a widely discussed basin-like

depression in South Germany (5) with a diameter of approximately 21 kilometres in a north–south and 24 kilometres in an east–west direction, covering an area of 380 square kilometres. When approaching this basin from all directions the mesozoic sediments exhibit geological disturbances and abnormalities in a roughly concentric ring of 10 to 24 kilometres, a zone which has been called Vorries by German geologists (Fig. 1).

Very similar conditions are to be found at Lake Bosumtwi, clearly expressed

Fig. 2

on the small-scale map accompanying Maclaren's paper and reproduced above (Fig. 1) but apparently not recognized by him. The lake is surrounded by a concentric ring of elevations, separated from the actual caldera rim by a peripheral depression and marked on Maclaren's map as the Buonim Watershed. Roughly following the caldera rim it merely shows a narrow outlet in the east towards the Anum stream; the width of this outer depression varies between half a mile and 2 miles.

Detailed geological mapping of the country around the lake, particularly to the south and east, revealed that the strike and dip of the old Birrimian schists, shales, and phyllites show a remarkable regional consistency, *i.e.*

north-east–south-east, ranging from 30° to 60° and with a dip towards the north-west. But as soon as one approaches the lake, constant disturbances are found, strikes and dips become quite irregular, frequently within a few yards. This is very well exposed along the road from Mpaha to Yabisa, particularly around Adato village. In certain parts, as for instance between Adakabunsu and Adato, the Birrimian phyllites definitely dip towards the lake; in other parts, as for instance between Tepaso and Isasi, they dip away from the lake. In most parts they are irregular.

The mere fact that the pre-existing metamorphic rocks around Lake Bosumtwi exhibit signs of great tectonic dislocations in a country which is regionally uniform suggests that whatever caused the lake depression also caused these dislocations. This means incidentally further evidence against the meteoric theory, for the impact of a meteorite would truncate the country rock but not cause complicated structure.

The fact that along the periphery of the lake the dips, where towards it, appear to point radially towards the centre of the caldera demonstrates that whatever forces caused this structure originated from the bottom of this lake depression.

Certain lake deposits of recent age (which will be fully dealt with later) in the vicinity of Banso, Dampa, and Juasi exhibit rough horizontal jointing. In a stream-bed south of Juasi these deposits dip 15° to 20° north, *i.e.* towards the lake. A slight dip towards the lake is also to be noted in an exposure of such young clays above Abonu village. Similar observations have been made by the Geological Survey in bedded sands (4). This proves that whatever movements caused the inverted dip continued long after the catastrophic act of caldera formation, even after considerable freshwater sediments had been deposited and raised from the bottom of the lake. But this is definite evidence against meteoric origin. The impact of a body burying itself deep into the earth would be one sudden act, merely followed by a short period of sagging. The more one is able to drag the apparently sudden process of formation of the Bosumtwi depression into different phases, the less the meteoric theory can be upheld.

Thus one can divide the flanks of the depression into three zones: (*a*) an inner zone, the actual caldera and subsided flanks of Birrimian country rock, with an inward dip; (*b*) a neutral zone, the rocks being more or less in a horizontal position or broken up by fractures; (*c*) an outer zone, with the Birrimian rocks dipping generally away from the caldera with a gradual change, according to the distance from the centre of disturbance, to the normal structure of the Birrimian rocks in Ashanti.

The ideal section in Fig. 3 shows the structure of the lake depression and vicinity. The three zones are represented morphologically by the Inner Depression (up to the actual caldera rim), consisting of the subsided rocks; the less pronounced Outer Depression, this being the neutral zone; and the Outer Rim comprising the Birrimian metamorphic rocks dipping away from the caldera (*vide* Figs. 1 and 3).

These conditions are well demonstrated along the Kumasi–Abonu Road, between Kuntanasi and Abonu Resthouse, approximately one-third of a mile from the latter. Approaching the lake from inland one finds Birrimian dipping

towards north-north-west, that is, away from the lake. Going farther one finds a very distinct fault-line (Fig. 4) separating these outward-dipping rocks from a mass of Birrimian showing irregular structure. Farther on (approximately one-eighth of a mile) the well-schisted Birrimian exhibits south-east dips, that is, towards the lake, and these conditions continue down to the bottom of the lake depression.

Whether an original doming-up of the overlying strata took place through the act of explosion cannot be proved with certainty. The general dip of the Birrimian in the peripheral parts in a direction radially away from the lake suggests that such took place, and undeniable irregularities in structure, as found to-day, are probably due to unequal forces in the process of throwing-up, fracturing, and subsidence, and to a certain extent later earth-movements. Earth tremors, even nowadays, are not unknown around Lake Bosumtwi,

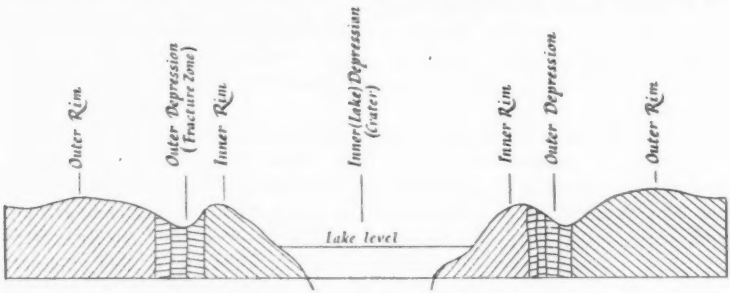


Fig. 3

the last one, approximately twenty years ago, having destroyed the house of the Chief of Abonu [1] (3).

Certain sound phenomena known from the lake (3), which will be discussed later, are in the author's opinion of a subterranean origin, as known from many localities all over the world. They usually occur in districts of young earth-movements and are thus to be interpreted as the dying out of orogenetic processes.

The magnetic disturbances first ascertained by Maclaren and recently confirmed by another observer, which were regarded by the former as strong evidence in favour of his meteoric theory, should in the author's opinion be interpreted as the attraction caused by a magmatic body below the lake depression, probably of basic composition, *i.e.* the consolidated body of igneous material, which formed the reservoir of the Bosumtwi vent and through later subsidence caused the sinking of the overlying masses and the structural dislocations. It is of great importance that the same phenomenon

[1] According to statements made by the Chief of Ajuafo there may have been a misunderstanding as regards this incident. The Chief made the author understand that actual earth tremors were unknown around the lake. It frequently happens however that native dwellings are built on unstable, sandy ground close to the lake shore, and after torrential rains, the water rushes down the slopes of the caldera walls, underwashes the building, and the latter collapses.

has been observed in the Ries of Nördlingen, where according to geophysical observations (6) basic masses, a laccolith, must be sought at a depth not exceeding 2 kilometres.

Great steps forward as regards the solution of Lake Bosumtwi were made by McGregor's discovery of volcanic agglomerates in the bed of the Buonim (Boni) stream, 2^{1}_{4} miles east of Yamiyini, and recent finds of young agglomerates by Dr. Junner, near Banso, south-east of the lake. Both finds were confirmed by the author's observations. The main exposures of scoria and

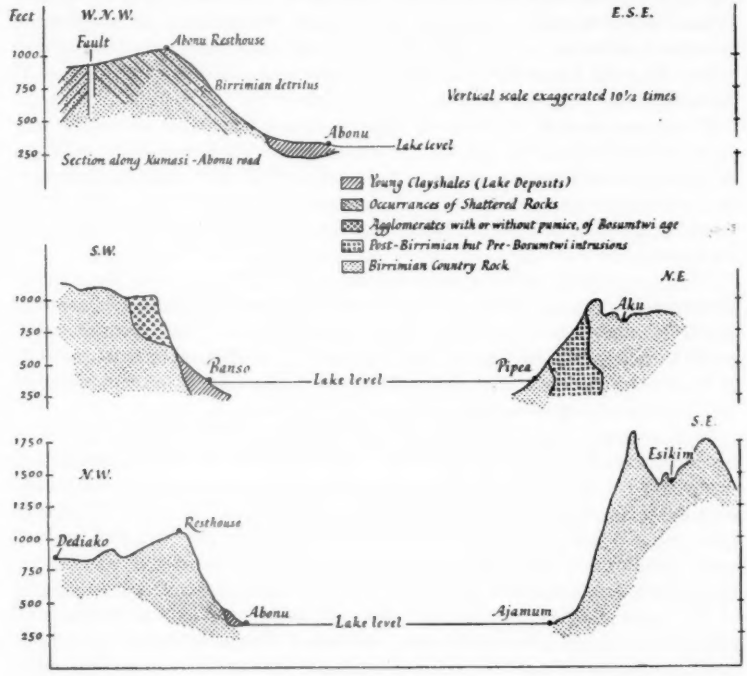


Fig. 4

agglomerates occur 0·25 miles upstream and 0·15 to 0·2 miles downstream from the place where the Nkowi–Yamiyini track crosses the Buonim stream.

The rock occurs mainly as boulders of various size, but is also found as large masses on the bank of the stream, more or less covered by thick vegetation. Here it can be regarded as *in situ*, and according to McGregor was at one place approximately 40 feet thick, resting on Birrimian phyllites; the latter are found outcropping all along the Buonim stream. The agglomerates are yellowish-grey, the matrix being an earthy, rather fragile material with occasional inclusions of much harder, altered igneous rocks, mainly granite, opaline quartz, and considerable quantities of grey pumice; indeed, as

McGregor rightly states, some of the material contains more fragments of vesicular glass than matrix.

The glassy material is irregular in shape; well-formed bombs are missing; and it resembles what is called *Fladenlava* in Germany, the largest of the inclusions being approximately 6 inches wide and 1 inch thick. Although highly vesicular, the pumice is not so porous as to float in water. A microscopic description is given by the Geological Survey.

The high content of 64 per cent. silica shows that the pumice belongs to the acid glasses, and with its high content of water it should be closely related to the liparitic or trachytic pitchstones. Remarkably low are alkalies, lime, and magnesia, and it certainly represents the Alkali or Atlantic Group rather than the Lime-Alkali or Pacific Group. According to Professor A. Lacroix, Paris, it represents a dacitic pitchstone.

It remains an open question whether these lava fragments are true representatives of the original lava, or have been altered by differentiation processes or absorption of the many different types of rock the vent must have pierced on its way to the surface. The fact that magnetic aberrations have been ascertained at the lake certainly suggests that the actual lava was of a more basic composition.

The agglomerates south-west of the lake occur well exposed in the stream-beds (Adensu, Aheshia) south of Apewu and 0·3 to nearly 1 mile south-south-east of Montaw and can easily be found at the stream crossings of the native paths from Montaw to Timiabu and Bosuma. The agglomerates occur both as broken-up material within the stream and also large rounded outcrops forming the bottom of these small streams.

It is an earthy, friable substance of dark-grey colour, iron stained and with small patches of white and yellow. The matrix consists of broken-up Birrimian material, more argillaceous than arenaceous. The small inclusions, scarcely ever exceeding half an inch in diameter, and generally very much smaller, are angular in shape and consist mainly of Birrimian phyllites and schists, partly graphitic, quartz fragments, laterite, and a yellowish-grey substance; the latter is very soft and weathered, probably originating from igneous rocks of Birrimian and possibly later age. The author found no actual evidence of young lavas, as in the Buonim stream, although it is possible that some of these undeterminable yellowish inclusions represent very much weathered pumice, altered by later pneumatolitic and hydrothermal action. As true lavas are missing there is no definite proof for the assumption that these agglomerates are connected with the origin of the Bosumtwi caldera. The following considerations however seem to point out that they can only be products of the eruptive phase connected with the latter.

The outcrops of agglomerates are quite undisturbed, without any visible joint or fissure. If the latter were of Birrimian age, the only other probable alternative, they would be sheared and schisted, as all the other Birrimian rocks in the vicinity; and if they were of pre-Bosumtwi age they would undoubtedly have been affected by the volcano-tectonic processes which, as shown before, dislocated the whole Birrimian complex in the vicinity of the lake. As the agglomerate contains innumerable fragments of the Birrimian rocks, which are *in situ* all around the lake, and even fragments of quartz of

post-Birrimian age, it must be younger than all its components. The highly friable material would never have lasted as a solid rock outcrop since precambrian (Birrimian) age. All Birrimian tuffs around the lake are fine and even grained, suggesting far transport from their source of origin. This uneven-grained and coarse material definitely suggests near origin either from one great central eruption (the Bosumtwi depression itself) or from minor local vents.

It is of interest to compare this explosive volcanic material of Lake Bosumtwi with the tuffs of the Ries of Nördlingen. At both localities actual lava flows are missing, although at the Ries the ejectamenta, bombs and lapilli, have partly weathered out of their matrix and accumulated, thus locally giving the false impression of a true lava flow; but just as at Bosumtwi there are occurrences which are practically free of any true volcanic material. In appearance the *trass* or *Suevite* of the Ries very closely resembles the Buonim agglomerate; both are highly vesicular and of acid composition, liparitic or dacitic. As at Lake Bosumtwi, the material is mainly found at a certain distance from the actual point of eruption, within the zone of the Vorries, giving rise to the important problem whether these agglomerates originated from one great central eruption or from epigenetic local vents in the vicinity of the caldera. This will be discussed later.

Among the various material of Birrimian age certain greyish-green rocks were found, mainly on the west side (between Dadiasi and Abonu), which in the author's opinion are volcanic tuffs. As they are decomposed and in no way differ from the Birrimian tuffs elsewhere found in Ashanti and the Gold Coast Colony we put them down as being of Birrimian origin.

As a unique feature of the Ries and also in the Steinheim basin, shattered rocks, consisting mainly of Upper Jurassic white limestones and precambrian granites, have been described and called ***Griesbrekzie*** by all German geologists. They consist of angular fragments of different size, irregularly distributed and recemented in a matrix of the same material. Large continuous masses of this material have been found ***in situ***, but more frequently such occurrences can be regarded as "rootless": vast pieces of float.

Similar occurrences were noted by the author in the Bosumtwi district. The most interesting find consists of two large blocks of Birrimian hornstone, one-eighth of a mile north-west of Yabisa, on the path to Ankasi. These apparently rootless masses consist of angular fragments of hornstone recemented in a highly siliceous matrix and so much resemble the ***Griesbrekzie*** of South Germany that, apart from the lithological difference, they might well be mistaken for one another. Specimens fully resembling this occurrence at Yabisa were found and brought back to camp by the author's colleague, Dr. T. G. Williams, from the vicinity of Kokobin.

Similar occurrences of shattered rock actually ***in situ*** are to be found three-quarters of a mile west of Ajuafo on the path to Patiensa, exposed in a streambed. Occurrences just below Abonu Resthouse are of doubtful origin, as the source of most of the material is not determinable. One piece of shattered granite was found as float between Abasi and Brojum, very close to the lake (west side). In the author's opinion these shattered rocks cannot be inter-

preted as fault-breccias in the usual sense, but just as the *Griesbrekzie*, due to volcanic forces, which broke up and dislocated the originally undisturbed sediments.

Although genetically closely related, volcanic breccias are to be separated from shattered rocks as a higher degree of volcanic dislocation. In this sense volcanic breccias are loose material, generally of different petrological composition, whereas the shattered rocks are sediments badly shattered, but either still *in situ* or else cast away *en bloc* as large continuous lumps of rock giving at times the false impression of actual outcrops. The equivalent of these volcanic breccias in the Ries is the material which has been called *Bunte Brekzie* or *Bunter Riesschutt* by different German geologists, these terms suggesting that it is an unsorted mixture of representatives of all horizons within the Ries or precambrian, mesozoic and neozoic age. As the Ries is a caldera of outspoken mature physiography (Upper Miocene age), one finds this unsorted material covering a considerable area of the caldera bottom, sides, and vicinity of the depression.

The Bosumtwi caldera being highly juvenile, partly even of a precipitous nature, renders accumulation of loose detritus on the slopes impossible. But although the neighbouring country beyond the caldera rim shows very few lithologic aberrations from the normal Birrimian phyllites and sericite schists, the beds of the short streamlets, just before entering the lake, exhibit an extraordinary variety of rocks. The sources of the detrital material are mostly unknown. One can therefore only assume that they are broken-up material, originating from the various horizons and caused by volcanic forces. Incorporated in this material are undoubtedly the fault breccias of the Geological Survey. As apart from minor fracturing due to the later process of subsidence no signs of tectonic movements were found by the author he is inclined to regard all these breccias as being of volcanic origin.

A strange phenomenon was encountered when traversing between Adato and Juasi south of the lake. Approximately half-way, on the actual slope of the caldera, the dark dense Birrimian quartzite, locally called hornstone, which is here associated with graphite, sericite, and chlorite schists and lateritic alteration products showed peculiar semicircular marks, hitherto unknown to the author (7). Whereas the hornstone when fractured generally exhibits rough surfaces, these well-defined marks were entirely smooth and covered with what appeared to be a thin siliceous film; the diameter of these figures varies from 1 to $2^1/_2$ inches; the colour is definitely darker than the hornstone itself, practically black. No radial structure is to be found on the surface.

Although there is a superficial resemblance to certain fossil imprints as Pecten, Rafinesquina, or Ortothetes, there can be no doubt that these marks are of inorganic origin; they are neither due to weathering processes, as blocks of such Birrimian hornstone when split open exhibited these figures on the freshly exposed fracture surface, nor are they concretions, as they do not form any closed body of spheroidal shape, but merely a thin skin-like layer within the cherty Birrimian rock.

The only analogues, though slightly different in appearance, are certain semicircular striated surfaces in the Upper Jurassic limestone of Steinheim

am Albuch, South Germany, resembling some problematic algae, like Cancello Phycus, Taonurus, etc.; these were first described by Branco and Fraas (5), and have since been found by all geologists examining and visiting the Steinheim basin, including the author. Although the origin of these so-called *Drucksuturen* has never been explained in a satisfactory way, they are generally regarded as being due to pressure-effects of volcanic explosions. The recent finds of the author are being closely examined at Berlin University and the Prussian Geological Survey.

In agreement with what is known from South Germany, *i.e.* no post-volcanic activity in the Ries and scanty aragonite in the Steinheim basin, the signs of post-volcanic activity around Lake Bosumtwi are very scarce. The only signs found by the author were occurrences of anhydrite in the Birrimian rocks, half-way between Adikabunsu and Timiabu. The white semi-translucent, prismatic crystals were well shaped and several inches long. No other specimen of anhydrite was found during the six months of prospecting work in the vicinity of the lake. Minor mineralization of the Birrimian rocks is so frequent within the Gold Coast Colony and Ashanti that one would be unjustified in trying to force a connection with the volcanicity of Lake Bosumtwi.

Noteworthy are however several other phenomena, partly of a legendary nature. An old saying among the inhabitants around the lake is "Bosumtwi has fired or exploded gunpowder" (Bosumtwi oto atuduru). At irregular intervals once or twice a year, but apparently not within recent years, the lake becomes rough for one or two days, the colour of the water changes to almost black, the surface is covered with dead and dying fish, and the atmosphere becomes full of a choking smell of "gunpowder." This phenomenon is accompanied by a loud detonation. No rumblings or earth tremors are noted. Although never observed by any European and never mentioned by the natives, this phenomenon is well known to every lake dweller. The recent volcanic origin of Lake Bosumtwi immediately suggests exhalations of gases, in particular hydrogen sulphide. According to T. Robertson (3) such upheavals are due to gases from decomposed organic matter at the bottom of a lake without any outlet, in particular to marsh gas. This explanation would also account for another phenomenon, mentioned by Sir Albert Kitson, *i.e.* "flashing lights, making noises like the discharge of artillery." The Chief of Abonu however gave Rattray the equally matter-of-fact and convincing explanation that these mysterious lights were deliberately caused by thieves robbing other people's nets at night and taking fire in a bowl to scare away the highly superstitious and easily frightened lake dwellers. Chemical analyses of the waters of Lake Bosumtwi showed them to be of the alkaline-carbonate type according to information received from Dr. Junner.

Although these periodic upheavals of the lake bottom might give rise to minor local explosions, it is impossible that these small detonations should be heard far away from the lake as has been reported frequently. Particularly interested in this phenomenon, the author tried to make his own observations during the whole time he spent in Ashanti and also during his visits to the lake, on which he usually spent the nights at the caldera bottom, close to the lake

shore; owing to blasting operations (Esikim, Kokofu, etc.), night hunting, and native ceremonies in this thickly populated district, during which firearms are frequently discharged, it was impossible to come to any reasonable conclusions.

Underground sounds, described as rumbling noises, gun shots, or detonation of artillery firing, are known from nearly all countries of the world. They have been reported from large lakes, for instance from Scotland and Ireland (Lough Neagh booms, Carlingford Lough). It appears that they occur particularly at localities of recent earth movements.

Within recent years young lake deposits, mainly varved clay-shales, up to 150 feet thick, have been found in parts adjoining the lake, but also up to half a mile inland. They are mainly developed at the mouth of the larger streams, as at Banso, Juasi, Bodekwano, also at Ajuafo and probably under the dense vegetation in the valley trending north-east from Konkoma towards Beposo. In addition small deposits of sand and gravel are found close to the lake.

These clays contain a considerable amount of fish and plant remains, the definite age of which has unfortunately not yet been determined. They appear to be exceedingly young. According to Dr. Junner the plant remains will shortly be examined in England.

These deposits mark a period when the level of the lake was decidedly higher than nowadays. This is particularly remarkable as many decades ago the water-level appears to have risen, actually forcing the lake dwellers more than once—at Abonu even four times—to remove their villages away from the lake shore. This fact is best demonstrated by the huge trees standing within the water of the lake, in some cases even as far as a quarter of a mile from the dry land.

About half a mile south of Juasi the author noticed in these well-stratified clays a distinct dip of 15° to 20° towards the north-north-west; above Abono village there was a slight dip towards the south-east, whereas the Geological Survey noted near Banso dips of 15° to 25° towards the north-north-east. That is, each time towards the centre of the lake.

Normally these clays must have been absolutely horizontal at the time they were deposited; the tilting of these beds is the best proof that subsidence of the lake bottom has taken place, even after the formation of the clays. The continuity of these hitherto undisturbed deposits was broken up to a certain extent by this process, as is shown by vertical jointing in the vicinity of Juasi, which divides these deposits into rough pillars. The author does not see the slightest evidence for Maclaren's statement that the fall of the lake waters from 480 to 270 feet above sea-level was sudden and catastrophic in character. The process was probably gradual. If the bottom of the lake has sunk and the basin thus become enlarged, it is quite possible that the actual quantity of water within the lake has never decreased, but remained stable, if not even increased. At the same time the apparent constant rise of the water-level nowadays does not necessarily imply that the downwards movement of the lake bottom has altogether ceased.

Maclaren (1) states that the lake has been rising "at the rate of 1 foot per annum for the last seventy years," but does not give the evidence. As even

nowadays with three motor roads leading to the lake there are only a few European visitors at very irregular intervals, the figure can be based merely on native information. Only recently has the Geological Survey erected a measuring pole in the lake at Isasi, which will enable accurate recording and give reliable figures for the annual increase within the next decade or two.

The occurrence of young freshwater deposits within the caldera depression forms a further link with the Ries of Nördlingen and Steinheim basin. The Ries depression became a freshwater lake in Upper Miocene times, and beds of clays, marls, limestones with intermittent thin layers of coal and lignites were deposited. The Steinheim basin was also filled in by water which deposited marls, clays, sands, and thin layers of limestone containing the well-known Steinheim fauna of Sylvestrina (Upper Miocene) age. Thus Lake Bosumtwi represents geologically the Ries of yesterday and morphologically also the Steinheim basin in Upper Miocene time.

In constantly comparing Lake Bosumtwi with the Steinheim basin the author relies on the morphological resemblance. Contrary to the general German point of view he is not convinced of the volcanic origin of the Steinheim basin, as any definite proofs are so far missing (5).

The most vital problem concerning the origin of Lake Bosumtwi is the question: What actually explains the great depression now filled in by fresh water? Is it due to one great phreatic eruption, *i.e.* a true explosion crater, or due to later subsidence, *i.e.* a sunken caldera? The question cannot be answered with certainty, since the material forming the bottom of the lake is unknown; no tuffs, agglomerates, or other indications for a vast central eruption have so far been found within the actual depression; on the east side of the lake between Bodekwano and Konkoma the Birrimian phyllites, although dislocated, are still to be found *in situ* within only a few yards of the lake. Thus nowhere on the flanks or at the shore of Lake Bosumtwi is the actual feeder of the volcano exposed, and if the latter exists it is to-day entirely covered by water.

Recent hydrographic work by the Gold Coast Geological Survey has shown the lake bottom to consist of a comparatively shallow shelf in continuation of the land and then a sudden drop towards the centre of the lake, the maximum depth hitherto recorded being 232 feet. This sudden change in contour could be well explained as the upper end of a funnel-shaped volcanic vent, which if actually existing would prove that the depression as such is mainly due to a phreatic explosion.

Within the last decade many of the vast circular depressions in areas of recent volcanicity have been interpreted as due to subsidence; many German geologists prefer this mode of origin for the Ries of Nördlingen and the Steinheim basin. But just as in the Ries, the actual products of eruption in the Bosumtwi district do not occur within the depression but outside, in a ring roughly following the outlines of the caldera rim. One can interpret this as due to a central eruption.

If such an eruption ever did take place, and there certainly would be no reason to assume more than one, the latter must have been of an "embryonic" type, a violent paroxysm of steam with very little lava material of intermediate composition.

Unquestionably a considerable amount of pre-existing country rock, mainly Birrimian metamorphics, was thrown up and redeposited, partly as loose angular breccias, partly as ashes and very fine-grained fragments forming the material found now in the south-west corner of the lake. The country rock *in situ* was thrust into such a position as to show a general dip away from the centre of volcanicity. Freshwater sediments, clays, sands, and gravel were deposited on the lower flanks of the caldera depression; gradual subsidence of the magma below caused the upper parts to fall in, the level of the lake sank, the originally horizontal layers of clays were tilted towards the lake centre. This process caused dislocations of the peripheral portions of the caldera, dividing the latter into three parts: an inward and an outward dipping zone with a neutral zone in between. Unequal weathering of these three zones caused the conspicuous geomorphological features we find to-day.

The lake has no outflow; all rain water on the rim and slopes flows into the lake depression and as accumulation greatly exceeds evaporation the level of the lake is constantly rising.

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The author was also in correspondence with Dr. N. R. Junner, Director of the Gold Coast Geological Survey, with the Secretary of the R.G.S., and Professor A. Lacroix, of Paris.

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THE ROMAN *LIMES* IN SYRIA

LA TRACE DE ROME DANS LE DESERT DE SYRIE. LE LIMES DE Trajan à la conquète arabe. Recherches Aériennes (1925–1932). By A. POIDEBARD. Introduction by FRANZ CUMONT. (Haut Commissariat de la Republique Française en Syrie et au Liban. Service des Antiquités et de Beaux Arts. Bibliothèque archéologique et historique, Tome XVIII.) *Paris: Libraire orientaliste Paul Geuthner* 1934. 11×9 *inches; (text)* xv+213 *pages; (separate atlas of)* CLXI *plates (with Avertissement* viii *pages and List,* 11 *pages); map, text and plates*

THIS fine publication, remarkable alike for the importance of its subject, its lucid exposition, and its magnificent illustrations, presents the results of the archaeological and geographical researches which Père Poidebard, S.J., devoted during 1925–1932 to the exploration and study of the Roman *Limes* lines on the eastern borders of Syria. Carried out with the effective collaboration of the French Air Force in the Levant and the constant support of the French administration in the mandated territory, these researches have been rewarded by results of far reaching interest not merely for the archaeologist and historical student in general but also for the geographer. Documented in the text and the plates with admirable fullness and clarity they illustrate in a most impressive way the extent and value of the help which archaeological exploration and geographical study both in respect of physical features and historical topography can derive from aviation. The importance of this help receives its most fit recognition in the fact that Père Poidebard's work is published under the joint auspices of the Académie des Inscription et Belles Lettres and the French Air Ministry. The former, the oldest learned body guiding antiquarian study, has reason to feel proud of having from the start accorded its support to Père Poidebard's plan of utilizing the aeroplane for his archaeological investigations.

The admirable introduction which M. Cumont, a foremost authority for the history of the ancient Near East, has contributed to the work, brings out very clearly both the importance of the border line over which Rome kept guard for over seven centuries in defence of Western civilization, and the special physical conditions which seemed as it were to predestine the aeroplane as an essential aid for its proper exploration. That Syrian Limes which gradually developed, as elsewhere on the far-flung frontiers of the Roman Empire, as a system of protected lines of communication, lay practically throughout across what is now desert ground. The search for its remains has attracted the attention of scholars ever since towards the close of the last century the study of the Roman Limes system elsewhere along the other borders of the Empire in Europe and Africa had become a fascinating subject of antiquarian and historical study. The journeys of such distinguished savants as Chapot, Brünnow-Domaszewski, Herzfeld-Sarre, and Musil, had revealed the survival of manifold traces of the hold which Rome had established over vast tracts of desert for the sake of protecting its provinces by the eastern Mediterranean against nomad raids and invasions of that hereditary enemy, the Parthians and Persians. But the extent of this border line stretching from the Province of Arabia in the south for more than 600 miles to the Tigris, the practical difficulties of prolonged travel on desert ground bare of essential resources, in parts even of water, and last but not least the obstacles raised through insecurity and official obstruction under the Turkish régime rendered impossible a systematic exploration of all Limes sections and the co-ordination of such archaeological data as had been gleaned.

The Great War, destructive of so many intellectual values, gave rise here to

changes favourable to progress. It brought enlightened administration to Syria through the French mandate and developed a marvellous means of observation in aerial photography. Père Poidebard had his first opportunity of personally realizing the range of geographical observation from the air when in 1918, being attached to General Dunsterville's force, he flew across the plateau of Persia. The idea then conceived of tracing ancient routes by means of aerial photography where obscured or hidden by changes on the ground, was confirmed by what a geographical reconnaissance in Syrian territory between Euphrates and Tigris had showed him in 1925. Entrusted by the Académie des Inscriptions with an archaeological mission on the same ground and valiantly aided by the technical experience and personal zeal of highly trained pilots and photographic experts from the French Air Force, he was able during the years 1926–1928 to develop his methods of archaeological survey, combining observation from the air and on the ground. Of the results thus obtained down to 1932 the beautiful photographs and detailed plans contained in the atlas present a truly impressive record.

In Chapter I Père Poidebard gives a very instructive account of how through the enthusiastic collaboration of archaeological observer, pilot, and photographer, it became possible to recognize, trace, and fix on the photographic plate the lines of ancient roads invisible on the ground (see *e.g.* Plate XCIII, C). They afforded guidance over long distances to remains of ruined posts, old wells, signal stations, etc., which otherwise might have completely escaped diligent search on the uniform flat expanse of the steppe. Details of the technique of flying and observing in varying atmospheric conditions, lucidly explained, show how even the faintest variations of the ground can be made to yield their unmistakable record if photographed under the slanting rays of the sun, even in atmospheric conditions which might well seem prohibitive. Astonishing results were obtained also, as Plates IX, XCI show, by photographing at low elevations almost full face to the sun in the dazzling light of the desert summer. Père Poidebard with that scrupulous fairness which throughout very pleasantly distinguishes his text does not fail to refer to archaeological records of interest achieved before by others from the air, such as those of Colonel G. A. Beazeley near Samarra (see *Geogr. J.*, 1919, vol. 53, pp. 330 *sqq.*) and to those recorded in Mr. O. G. S. Crawford's important publications. But it may well be doubted whether any previous observations were ever so helpful in directly guiding to important archaeological results as when air photographs taken along the Limes line following the Khabur river enabled P. Poidebard to distinguish and exactly to measure the remains of Roman castella which, buried in the loess-like soil covering the top of far more ancient *tels*, were on the ground quite invisible to the eye.

Père Poidebard justly stresses the advantages he enjoyed in being able to follow up ancient lines of communication first by reconnaissance flights done for hundreds of kilometres at low elevations. This, no doubt, greatly facilitated arrangements for the detailed examination of their still traceable remains, which wherever practicable was subsequently carried out on the ground. Equally important must have been the saving in time and trouble where accurate measurements of sites and physical features could be secured by the methods he indicates without the need or possibility of descending to the ground, as *e.g.* in the lava-covered wilderness of El Leja. Even so these explorations, continued often into the torrid heat of the desert spring and summer, must have implied very serious hardships. But of these P. Poidebard rarely allows us to get a hint, and of the risks unavoidably run characteristically enough he is completely silent.

The researches carried on for the last fifty years on the different frontiers of

the Roman Empire have proved that the Limes established along them consisted everywhere from the start of a system of protected routes forming a defensive zone along the border. Basing his remarks mainly on the masterly summary of those researches contained in Professor Fabricius' article on the Limes in the *Real Encyclopaedie* of Pauly-Wissowa, Père Poidebard in Chapter II shows how that recognized Limes system was with characteristic suppleness adapted to the special needs of the Syrian border. These were on the one hand defence of the settled provincial territory against the ever-threatening danger of Parthian and Sasanian invasion, and on the other protection of the routes passing beyond the administrative border—to use the term familiar from the Indian N.W. Frontier—through tribal areas not directly controlled. These routes needed guarding for the sake of trade and for the prevention of raids.

The means directed towards this twofold aim were likely to have been the same as used by the Roman military organization on other frontiers of the Empire: permanent military camps, regular roads protected by forts, watch and signal stations. The systematic search for their remains has made it possible definitely to trace the line of the Syrian Limes as finally reconstructed by the Emperor Diocletian. But quite as instructive and interesting a result was the proof that consideration for important geographical features was here as elsewhere a determining factor in the organization of the Limes.

It is the careful study of the physical features both along the ground traversed by the Limes and in the desert areas controlled from it which renders Père Poidebard's work of particular value for the geographical student. The latter, quite apart from all the instructive details furnished about the configuration of the ground along the different sections of the Limes, will find an abundance of illuminating and well-documented observations on the climate, the available water supply, the *transhumance* represented by the seasonal migrations of the nomadic population, and on other factors directly influencing the economic conditions of this region both in the past and the present.

But as in all matters where human activity is concerned, historical developments also are bound to claim full attention in connection with this Limes. The influence exercised on it by changing political conditions and the military problems they gave rise to, have been noted by Père Poidebard with due critical care. The character of the Limes was bound to undergo considerable modifications in the course of events affecting Roman policy. From the time when Trajan pushed the northern end of the Limes forward to the Tigris in order to use it as the strategic base for his advance into Mesopotamia, down to the Emperor Julian's disastrous expedition followed by the abandonment of the strongholds of Nisibis and Singara in 363, the line underwent repeated fluctuations anyhow between the Euphrates and Tigris. The extensive reconstruction and consolidation effected by Diocletian at the close of the third century is a phase reflected more clearly than the rest by the ruins so far examined along the Limes. But it will need prolonged systematic exploration with the spade before full light can be thrown on the history of the Limes by the inscriptions and other antiquarian evidence to be recovered from its ruined stations.

P. Poidebard starts his survey of the Syrian Limes in Chapter III from the south where Busra, the capital of the Roman province Arabia, formed the nodal point of many important routes leading from the Mediterranean ports to the Persian Gulf, the interior of Arabia and due south to the Gulf of Aqaba and the Red Sea. A Roman road still clearly visible on the ground for the most part leads straight from Busra to Damascus, cutting right through the very difficult lava belt of El Leja. It can have been conceived only with the strategic aim of affording protection for the fertile tracts of the Hauran adjoining to the west. Père

Poidebard indicates adequate reasons for connecting this amazing piece of engineering with the *Via Nova* of Trajan leading from Busra to Aqaba. It forms in fact its direct continuation northward.

The line of this road with its watch-stations, Roman milestones, etc., had been noted in places before. But only the aerial survey carried out in 1927 under the direction of Commandant de Boysson, one of P. Poidebard's earliest collaborators, has made it possible to follow the line right through and to appreciate fully the exceptional difficulties overcome in constructing this road across such forbidding ground. They are strikingly illustrated by the photographs reproduced in Plates XII, XIII. A detailed study of this protected road was subsequently carried out on the ground by M. Dunand and is summarized by P. Poidebard. It shows the extreme care taken to watch ground which owing to its very nature would have afforded a convenient screen for the unobserved approach of raiders.

A second road, similarly protected, which has been traced skirting the eastern foot of the Jebel Hauran and then that of El Leja helped to secure that essential trunk line linking Busra with Damascus. The latter great economic centre of Syria was bound by its position and resources to serve as the chief base for all communications towards Mesopotamia. Regard for these, as well as the geographical configuration of the hill chains thrown out here by the Anti-Lebanon, necessarily caused the line of the Limes to turn from Damascus north-eastwards to Palmyra. Of the three possible routes leading to this important old oasis, the one leading along the southern foot of the Jebel Rawaq and its north-eastern continuation is proved by its succession of castella and watch-stations established at regular intervals to have served as the main fortified Limes line. First followed right through by that distinguished Arabist and explorer, A. Musil, this "Road of the Hans," as the Bedouins call it, can now in the light of P. Poidebard's thorough surveys and epigraphical finds be definitely recognized as the *Strata Diocletiana*. Thus the milestones discovered in numbers along it call it after the great reorganizer of the Limes.

It is on this section of the Limes, perhaps more than on any other, that the grasp of those old military engineers combining traditional Roman regard for regularity with a sharp eye for topographical features displays itself very strikingly. For a distance of fully 140 miles the Limes line lies along the foot of barren hill chains, and the character of this desert ground has allowed all details of its organization to survive in remarkable clearness. The castella marking the main stages of an average of 30 miles (*mille passum*) and the intermediate minor posts at distances varying from 10 to 12 miles, are always placed where passages through the hills behind and caravan routes crossing them towards the grazing grounds in the desert to the east and south could be most effectively guarded.

Wells or cisterns carefully constructed on ground in close vicinity to the defensive posts assured safe access to water. Their provision proves that the conditions of rainfall did not differ then essentially from the present ones. Watch-stations still traceable on commanding heights assured throughout a complete system of optical signals along the line. Excellent air-photographs like those shown in Plates XX, XXVII, XXX, XXXVIII, XL, together with a wealth of detailed plans prepared on the ground, allow the student to visualize not merely the ruins of the station, but the barrages, canals, and reservoirs constructed under their protection for the capture and use of the seasonal rainfall. The study of such an *organization agricole*, *e.g.* as Plates XXXII–XXXVII admirably illustrate between the stations al-Basiri and Qasr-al-Her, is of absorbing interest also for the geographer.

Before leaving this section of the "interior Limes" brief reference may conveniently be made also to a series of outlying protected lines connecting Busra with the *Strata Diocletiana* or directly with Palmyra. Their detailed description (pp. 57–70) throws very instructive light on the care with which the natural passages left between the great volcanic plateaux in the *Harra* to the north-east of the Jebel Hauran were guarded. The protected routes passing them provided control also over the numerous basins or *Hafras* in that area which, collecting the drainage of great wadis, afforded then as now important winter grazing grounds for nomadic tribes. Père Poidebard rightly emphasizes the fact that this network of secondary Limes lines crossing or passing to the west of the imposing great crater (Plates LIV–LVIII) of Jebel Seis, the *Mons Jovis* of the *Notitia dignitatum*, afforded also protection to the fertile basin below Damascus. The richness of this ground and its exposed situation where the main Limes makes a marked bend, must have at all times made it an attractive goal for nomadic raids as well as invasions across the desert.

The oasis of Palmyra, owing to its geographical position and the facilities for plentiful irrigation assured by its spring, was predestined for the rôle it has played as the natural centre for great trade routes through the desert connecting the Mediterranean ports with lower Mesopotamia and Arabia. Its historical importance is impressively illustrated by the abundance of its surviving monuments of which Plates LXV–LXVII reproduce splendid air-photographs. Palmyra owed its wealth and power, so disproportionate by comparison with its local resources, solely to the trade for which the wisely conducted policy of its merchants had made it the great emporium during centuries. As long as the Venice of the Desert, as M. Cumont has very fittingly called it, succeeded in maintaining its rôle as a more or less independent buffer state between Parthia and Rome, the escorts furnished by its mounted archers, the *Sagittarii Palmyreni* of the inscriptions, and its armed camel-riders, such as votive sculptures at Palmyra show them, assured security for the caravans traversing the desert towards Babylon, Seleucia, and Charax at the head of the Persian Gulf.

The fortified posts which Père Poidebard has been able to locate along the routes leading from Damascus and Palmyra towards Hit and the lower Euphrates and which in Chapter V he discusses as part of the Exterior Limes, seem all to date from the time when Rome after the revolt and downfall of Palmyra under Odenathus and Zenobia had to take direct charge of the task of protecting these routes against nomads of the desert and invading Sasanian cavalry. It is perhaps significant that along the direct route leading from Palmyra to that remarkable ruined site, the town of Dura on the Euphrates, which founded as a Macedonian colony by Seleucus had for five centuries maintained itself under the protection of Palmyra and a Roman garrison, not a single fortified post is found. Until Dura was abandoned about the middle of the third century to the Persians, protection on the route by fixed posts was apparently not needed, and after that withdrawal there was no longer any traffic to protect on that route. Trade on the routes also farther south is likely to have greatly diminished during Sasanian times, when the great Central Asian route which served the valuable silk trade from China to Persia was gradually replaced by maritime intercourse through Indian waters and the Red Sea.

From Palmyra, which an extensive fortified line defended, anyhow since the final Roman occupation, the Limes was bound to continue north-eastwards to the Euphrates for both geographical and political reasons. There alone the configuration of the ground provides natural support for a strong defensive zone. It is found in the system of hill chains dominated by the Jebel Abu Rujmein which starts from the Valley of the Tombs immediately behind Palmyra. Beyond

Es Sukhne that system continues in the same axial direction by the Jebel al-Bishri right through to the Euphrates. The rugged nature of this range by itself provided a strong outer defence for the road which was constructed already A.D. 75 by M. Ulpius Trajanus, legate of Syria and father of the future Emperor Trajan. It was intended to assure the direct connection of Palmyra with the Roman fortress of Sura on the right bank of the Euphrates. By that time Rome had already advanced its hold well into the great bend of the river, the quadrilateral of the ancient Osroene. There existed thus strong political and military reasons for linking up this base against Parthia by the most direct route with Palmyra.

Two centuries later this road was destined to become the northern extension of the Limes as followed by the *Strata Diocletiana* and duly marked with its stations and distances in Peutinger's famous *Tabula*. It was first explored by Musil, and it can now be studied, with all its topographical and archaeological details lucidly described and abundantly illustrated, in Chapter IV of P. Poidebard's work (Plates LXIII–LXXX). The same careful disposition of the fortified *castra* and *castella* is observed here, the same ingenuity and thoroughness in safeguarding and utilizing all resources of water. The extreme value of air photography revealed itself here also by allowing the remains of Roman settlements to be traced even where they are effaced and overlaid on the surface by Arab villages or modern cultivation.

At Risafa are seen the extensive ruins of the ancient Resapha, later called Sergiopolis, which was the last main station before Sura. Père Poidebard's close attention to hydrographical features enables us to understand how this considerable town (Plate LXXV) could provide itself with an adequate supply of water owing to its geographical situation where the subsoil drainage of numerous wadis converges. The location at Qseyr-as-Sele, 10 miles north of Risafa, of the *Tetrapyrgium* where the great saints Sergius and Bacchus suffered martyrdom under the Emperor Maximinius Daza (305–313) is of interest. It affords striking proof of the accuracy of the record in the *Acta Sanctorum* which mentions the place exactly at the above distance.

From Sura, for centuries an important Roman stronghold on the Euphrates and noted as a legion's headquarters, P. Poidebard takes us down the river past the long series of fortified towns and castella which lined both banks as far as Circesium at the confluence with the Khabur. Ever since Diocletian definitely advanced the frontier on the Euphrates to Circesium, the present Bseyda, this double line of military roads formed an integral portion of the Limes. Already before that time and later too until the Emperor Julian's ill-fated expedition (A.D. 363) the convenient line of communication provided by the river had served more than once as the southern route for Roman offensives directed against Ctesiphon and Seleucia. Excellent air-photographs with plans based upon them allow us in P. Poidebard's work to see this historical ground with the imposing ruins of Zenobia, the narrow defile of Zelebiye, Roman camps not before surveyed, etc., better, perhaps, than if we visited it on the ground.

In the concluding portion of Chapter IV there are briefly noted the Roman remains so far traced on three lateral routes which branch off from the *Strata Diocletiana* near Es Sukhne and strike the river opposite Circesium as well as above and below it. In the same place P. Poidebard discusses the strategic reasons which account for the Limes making the great bend via Sura instead of running straight from Es Sukhne by the foot of the Jebel al-Bishri towards Circesium. The point deserves special notice since it is the latter line which is followed nowadays by a much-frequented route connecting Palmyra with Deir-ez-Zor on the Euphrates and the valley of the Khabur beyond it.

The ground traversed by the Limes between the Euphrates and Tigris offered

a rich but in some respects also a particularly difficult field for P. Poidebard's researches. This area now known as the Upper Jezireh had since Trajan's advance to the Tigris been constituted as the Roman province of Mesopotamia. For centuries it formed at intervals a base for the Roman offensive towards Mesopotamia and an immediate goal for the invading attacks of Parthians and Sasanians. Favourable conditions of climate in the north along the foot of the Armenian mountains, and facilities for irrigation afforded by the streams thence descending into the plain, made a great portion of this area rich in agricultural produce under Roman protection and may do so again now under that of the French mandate. These resources were bound to direct the efforts of Rome's Iranian adversaries still more towards this province. The necessity of elaborate defence thus imposed itself along this frontier. It accounts for the extensive system of Limes roads and fortifications which preceding archaeological tours of Oppenheim, Sarre, and Herzfeld had indicated here in outlines but which still awaited systematic survey.

In his introductory remarks of Chapter VI, dealing with the Limes from the Euphrates to the Tigris, P. Poidebard lays due stress on the physical factors which in this region of potentially fertile steppe explain both the abundance of ancient sites from Assyrian times downwards and the difficulty of determining their origin and character without prolonged work with the spade. Scattered all over this ground are to be seen great *tels* or debris mounds marking ancient occupation. On them the winds blowing during a portion of the year deposit layers of dust which retained by the vegetation growing on those mounds under the prevailing climatic conditions form a kind of loess crust impartially covering up remains dating from early prehistoric times down to the Byzantine and Arab periods. It needed the eye of the photographic lens used from the air to discover the traces left by the work of Roman engineers on the great flat-topped mounds which mark sites of Assyrian and perhaps still more ancient settlements. The difficulty here facing the archaeologist when confined to the surface of the ground and unable to carry out deep excavations is clearly brought home by air-photographs, such as those in Plates CVIII–CXVI which show the great mounds flanking in a long line the right bank of the lower Khabur.

It was along this river line affording a strong geographical barrier that Diocletian constructed his Limes from Circesium at the confluence of the Euphrates and Khabur right up to the present Haseche. There the Khabur receives its main tributary, the Jagjag, and there the French administration with the right eye for topography has placed its chief post towards the Iraq border. The great heights of the numerous ancient *tels* afford commanding positions and thus readily offered themselves for Roman camps and castella. Their positions can be traced here at the same regular distances as along other sections of the Limes. A short distance below Haseche there rises on the river's left bank the great *tel* of Tuneynir. It had been identified before by Herzfeld with the Thannuris or Thannurios of Byzantine records. But it needed aerial photographs (Plates CXV, CXVI) to reveal clearly the whole plan, Plate CXVII, of the great Byzantine stronghold, as well as the tower which Procopius' history particularly mentions as having been erected by the Emperor Justinian to serve as a bridge-head on the right bank.

From Thannuris started two protected routes linking the Limes on the Khabur with an advanced section carried along the eastern foot of the Sinjar range and having its chief place of defence in Singara, the present town (Balad) of Sinjar. Before referring to this section we may follow up the northern continuation of the Khabur line as P. Poidebard has successfully traced it along the Jagjag to the great Roman stronghold of Nisibis and its Byzantine successor Dara. Here

a line of castella placed at much shorter intervals, and frequently on both sides of the river, marks the increased importance attached to the defence of ground which lay particularly open to invasion from the Tigris. The Roman forts had here to be looked for on the very numerous *tels* lining the banks of the river, and the camera helped to trace them.

It was near one of these great mounds, Tel-Brak, that P. Poidebard could record a striking success of his method. Careful search on the ground and also from the air in 1925 and 1926 had failed to show him any indication of this strategically important position on the line having been held by Roman troops. Yet within a few miles around it not less than three Roman stations were traced. At last however in the autumn of 1927 after rain had wetted the steppe, the camera revealed the outlines of a fort at Tel Brak itself. Excavations made then with the help of a detachment of Assyrian troops readily furnished by the military authorities brought to light the remains of a castellum of the Byzantine period, and this was accurately surveyed (Plates X, CXXIV). Around it was traced a large circumvallation also of Byzantine times. Finally a photograph taken from a height of 2000 metres revealed near by also the large camp of a legion. On the opposite bank of the Jagjag an entrenched bridgehead was traced in which the *strigae* of Roman tent lines were still recognizable (Plate CXXII), just as I had seen those of an ancient Chinese camp far away on the Han Limes in the desert east of the Su-lo-ho.

To the west of the main Limes line extending along the Khabur and Jagjag P. Poidebard was able to survey the remains of a series of transverse roads constructed with a view to strengthen the defensive zone between the Euphrates and Tigris. These roads started from Nicephorium Callinicum nearly opposite Sura and from Resaina on the great military route connecting northern Syria with the frontier. They allowed reinforcements to be brought up readily both from the south and the west. In addition another road provided with fortified posts running more or less parallel to the Khabur–Jagjag line and at an average of 25 miles behind it served as a line "de rocade" between Palmyra and Mardin to the N.W. of Nisibis.

This whole system of military roads based on Diocletian's Limes from Circesium to Nisibis displays its defensive character quite clearly by its very direction from south to north. It was manifestly different with the protected roads which had been pushed beyond that line in the north towards the Tigris. They were meant to serve those efforts at offensive to be carried into Mesopotamia on which Rome had repeatedly started from the time of Trajan down to Julian's disastrous adventure. The main line for Trajan's offensive lay by the Tigris, and it was from Nisibis as his base that the Roman road protected by castella and camps, still traceable on portions of the ground, is likely to have been first constructed to Bezabde or Saphe on the Tigris. It follows a line along the foot of the Jebel Tur, where the ground was well adapted for defence against Persian cavalry. It was still sufficiently well known to local people to be chosen in 1921 to mark the Turkish–Syrian frontier.

Singara, the present town of Sinjar, first occupied under Trajan, formed the stronghold at the southern corner of the triangle which with Bezabde–Saphe in the north and Nisibis at its western point was meant to serve as the strategic base for the Roman offensive. A number of fortified camps and towns which P. Poidebard's aerial reconnaissances have traced in the steppe to the north of the rugged Jebel Sinjar are probably connected with the Roman road which Peutinger's *Tabula* indicates as linking Nisibis with Singara. But the location of the several stages which that old cartographical document names still remains uncertain.

It is different with the routes which led to Singara from several of the fortified stations on the line of the Khabur. They have all been exactly determined in the course of P. Poidebard's aerial surveys. The principal route connecting Thannuris with Singara and marked by fortified posts which could be identified in the itinerary reproduced by the *Tabula* of Peutinger, is of special interest. Where it skirts the low hills of the Jebel Chembe, P. Poidebard has discovered the remains of a well-built line of wall flanked by a double fosse (Plates CXLVI–CXLVIII) crowning the crest of the chain. Extending for about 6 miles between a marsh and two fortified camps it was meant to close a gap through which a Persian cavalry force might easily have forced its way to the Khabur.

It is a matter of regret that the Iraq frontier did not allow P. Poidebard to extend his reconnaissances, ever so thorough and fruitful, also along the southern slopes of the Jebel Sinjar. The town of Sinjar situated at its foot and still surrounded in parts by massive walls which in their foundations anyhow date from Roman times, undoubtedly represents the Roman colony of Singara first established by Trajan. The very steep and barren range rising behind it, until recent times always a safe retreat for those curious people the Yezidis, afforded Singara protection on the north. But otherwise this far advanced bastion of the Limes lay singularly exposed to attacks across the open plain of the Jezireh. It was repeatedly lost and retaken, only to be finally abandoned in 363 to the Persians after Julian's ill-fated expedition. Ammianus Marcellinus, in a passage which P. Poidebard quotes in connection with the town's inadequate water supply, was no doubt right when he noted of Singara: "Its possession was always rather disastrous for us, owing to the losses in men which its capture entailed in each case."

It seems very unlikely that a place so far advanced beyond the main Limes and yet so tenaciously clung to for centuries should have been left without an outer line of defences. To search for these is a task which might well be taken up on the Iraq side, with the help of the Royal Air Force, as a fit supplement to P. Poidebard's labours. The same remark applies also to a line of outposts of the Limes which on topographical grounds may be assumed to have linked Circesium with Singara. In the course of the determination of the Syro–Iraqian border (1932) such a post was indeed observed from the air at Tel-el-Heyl about 34 miles to the S.W. of Singara.

The summary account presented above of P. Poidebard's work may have served to convey a bird's-eye view, however imperfect, of a vast area over which Rome has left indelible traces of its constructive and protective domination. The fact of so much of this ground being what may be called "tame desert" and hence not subject to the constant changes attending civilized human occupation, must necessarily add greatly to the interests of its study not merely from the historical but also from the geographical point of view. Reference has already been made to the admirably clear and precise way in which all the characteristic physical features of the different zones traversed by the Limes are presented both in the text and by the magnificent series of air-photographs accompanying it. For the geographical student the abundant documentation here afforded must be all the more valuable because history and archaeology supply here an incontestable chronological gauge as regards any change in physical conditions in this vast area which might be assumed to have taken place during the last fifteen hundred years.

P. Poidebard in the concluding VIIth Chapter treating of the general organization of the Limes gives not merely a very useful synopsis of all essential antiquarian facts concerning the construction of roads, bridges, watch towers, and signal stations, but also fully discusses the questions, rendered all important by

the general climatic conditions of this region, as to the water supply available in Roman times and the means adopted for its agricultural and pastoral use. A separate section deals in detail with systems adopted for assuring the water supply at the Roman camps and posts, and at the stages of caravan routes. The technical construction of the wells, reservoirs, and cisterns; the means employed for safeguarding springs and catching the available surface drainage, are all described, partly with the help of exact data collected by French Engineer officers charged with surveying these installations of their Roman predecessors.

Of considerable interest is the account of the methods which were under Roman guidance adopted in the *Hamad*, the great desert south of the Limes, for conserving the rain water collected in the drainageless depressions (Khabras) well into the hot weather season by means of barrages and great artificially cut basins. The importance of these measures for the creation of grazing grounds is clearly brought out, and also the help thus afforded for the political control of nomadic tribes on the border. A careful study of the conditions prevailing in these nomadic grazing grounds has enabled P. Poidebard to throw light also on the extensive remains of indigenous defences which before had been very puzzling. The use made of barrages and reservoirs for providing irrigation in certain localities along the main Limes has been referred to above.

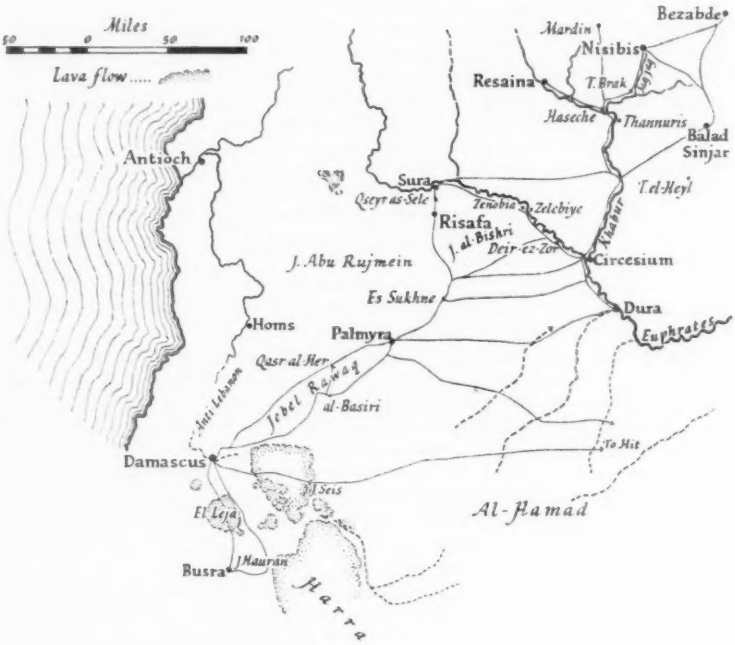
Much-discussed theories of general or partial "desiccation" in Asia have rightly been left outside the scope of this work. But from a critical study of the carefully observed facts which it records the conclusion imposes itself that the climatic conditions in this part of the Near East cannot have undergone any essential change since the time of Roman rule. The definite evidence here afforded deserves to be all the more valued by the geographer because it extends over a sufficiently prolonged and chronologically well determined period of history and is gathered on ground which has been left practically untouched by the complex effects of human activity.

The gain for historical research from the P. Poidebard's surveys by air and on the ground is so great that to do them full justice would mean reproducing almost *in extenso* the admirably clear and concise remarks with which the results are summed up in the concluding four pages of his volume. Nor is it possible here to mention any of the numerous instances in which inscriptions and other discoveries made in course of those surveys even without excavations have thrown striking light on the conditions of daily life once led on those borders. That a rich harvest still awaits here the spade of the archaeological explorer is certain. But it is a fundamental merit of P. Poidebard's labours to have definitely shown where it will have to be set to work.

As M. Cumont justly points out, nowhere perhaps over the vast spaces covered by the road system which Rome extended along with its conquests from the Tigris to the Atlantic, have the great qualities of Roman organizing genius manifested themselves more clearly than on this ground. "An intelligent and supple direction, a practical administration, have known how skilfully to adapt themselves to the geographical conditions of the ground, to the ethnic and social character of the populations, to the military tactics of the enemies who had to be repulsed." It is fortunate for the cause of research, just as it is in many directions for the economic and cultural future of this region, that the French mandate has been enabled here to resume the inheritance of Rome. Père Poidebard's labours have added much to that claim of high merit which French scholarship associated with such famous names as de Vogüé and Renan has established in Syria. They reflect equal honour also on that great Society to which he belongs and to the members of which scholarly research in the East has owed much for close on three centuries.

It must be earnestly hoped that the example set by Père Poidebard's researches and by the generous help of the Aviation française du Levant and the various administrative services in mandated Syrian territory which rendered their success possible, may lead to similar explorations on Rome's Arabian Limes now under the British mandate in Transjordania. The stretch of ground that remains to be studied there is considerably shorter, but its historical and geographical interest is not less. That northernmost Roman Limes which once protected England has for a long time past seen much successful work on the part of British archaeologists. It seems fit that attention be directed now also to that southernmost of Rome's Asiatic borders on which Britain at present keeps guard.

AUREL STEIN.



REVIEWS

EUROPE

THE BRITISH ISLES. By J. F. UNSTEAD. (A Systematic Regional Geography. Volume I.) *London: University of London Press* 1935. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* xii + 292 *pages; illustrations and maps.* 6*s*

In 1933, Professor Unstead, as Herbertson Memorial Lecturer for that year, chose as his subject "A System of Regional Geography." The essential feature of the system is that the study of the smallest regions or unit-areas is regarded as the basis of the work, which then proceeds to combine these unit-areas into larger and larger areas—regions of higher orders. In common with current usage in geography, the unit-area is regarded as an entity whose characteristics are determined by the interaction of all its living and non-living components. The unit-areas, or regions of the first order, are termed stows; these are grouped into tracts which in turn are grouped into sub-regions. A number of sub-regions make up a minor region, the major (Herbertsonian) regions of the world are made up of a number of minor regions.

Professor Unstead has planned a series of four text-books, covering the world, following this system, and the present volume, dealing with the British Isles, is the first. Geographers will be grateful for this early opportunity of judging the merits of the system. Difficulties are immediately apparent; a stow is "shortly defined as the smallest unit-area of geographical study" (p. 12) and the first example chosen is a "typical plateau stow of the South Downs between the Adur and Arun Valleys." Yet this stow is made to include such markedly contrasted parts as the Chalk Downs and the Littlehampton–Worthing coastal tract—so completely different in the sequence of their human occupance. Geographical field parties have long been accustomed to use the Isle of Wight as epitomising in miniature the Chalk Downs, the Weald, and the Hampshire basin; Professor Unstead finds it is only a complex stow (p. 87). Areas altered directly by man's activities present difficulties; thus London with its complex physical setting is regarded as a single stow (p. 49). The first difficulty is thus in the recognition of what is a unit-area. The second difficulty is expressed on p. 13. The ideal method of proceeding is that "all the stows of all the world should first be worked out and examined," but unfortunately this is "obviously not practicable." Hence as the survey extends, regions of higher order become the units. Actually the majority of the stows, tracts, and sub-regions distinguished in the British Isles do not differ markedly from those commonly used by geographers and which have been obtained by the process of *division* of larger units. In the large amount of detail, there is little that is novel, and whilst it is stated that "investigation of a region must be carried out in the field, and with the aid of maps on the largest scale available"—the latter part of which statement may be doubted—little attempt appears to have been made to utilize the ordinary Ordnance maps or various special detailed maps now available, and there is only a casual reference in the bibliography to "maps on various scales."

The geographer of necessity selects much of his material from the results of other sciences. The selection calls for both understanding and care. Unfortunately Professor Unstead's misuse of his geological material is so marked that, unless condemned by his fellow geographers with the utmost severity, it must bring the whole modern study of geography into disrepute.

It is curious that one who is attempting to bring greater precision to the study of regional geography by distinguishing regions of varying orders of magnitude

should deliberately ignore the carefully graded divisions of the time scale long used by geologists. Thus the Tertiary is divided into five "formations"—Lower London Sands (*sic*), London Clay, Bagshot Series, East Anglian Crags, Pebble Gravels. This is but one example of many. Archaisms are resuscitated, such as the continued use of "New Red" (wrongly as equivalent to the Trias), and the "Mountain Limestone (Calciferous Sandstone)" as the lowest division of the Carboniferous. There are ten geological sections in the book; one at least (Fig.50) is nonsensical; another (Fig. 27) obviously wrong, whilst others (such as Fig. 34) perpetuate facile generalizations which have been condemned even in elementary books. Of the thirty maps in the book twelve are maps of solid Geology and their use is surely a retrograde step when by placing them opposite maps of geographical regions a direct correlation is suggested. This is especially the case with the geological maps of Ireland, the northern coalfields (showing exposed Coal Measures only), and East Anglia. Looseness in thought and expression may be responsible for the confusion between soil and the Eocene strata of the London Basin (Chapter III), the reference to Wales as an example of "block structure," and to the position of leading buildings in London (p. 71), but cannot cover the repeated error regarding the position of Gravesend on the old route from Dover to London (pp. 50 and 61). The reference to the "port" of Deal (p. 51) is curious.

Professor Unstead's book is interesting as an exposition of his method; whether it will meet the needs of the post-matriculation courses for which it is professedly written, teachers must decide. In its present form its fundamental errors render it dangerous; one feels also the need for a very sound general knowledge of the geography of Britain since there is little help in welding together the details given of a very large number of stows and regions of minor order. L. D. S.

THAT BLUE DANUBE. By J. D. E. Evans. [*London*]: *Denis Archer* 1935. 9 × 5½ *inches; 248 pages; maps. 7s 6d*

This is an honest and skilful attempt to find the truth about the question of oppressed minorities in Central Europe after the Treaty of Versailles. The author deals mainly with Hungary, as the centre of both pre-treaty oppression and post-treaty discontent. He makes it clear that there can be no question of absolute justice from an ethnological point of view: that the oppressors of yesterday have become (though to a lesser extent) the oppressed of to-day; and that "no international pact, no treaty, no League of Nations supervision will change the position, unless the central authorities are inspired by a genuine desire to handle their minorities with justice and to act with real energy in their defence. Such an attitude is practically impossible to-day. Its first condition is a state of cordial relationship between the states whose nationals are concerned." The question of Transylvania—Hungarian before the Treaty of Versailles, Rumanian now—is most carefully examined. The ethnological ingredients of each district are gone into, and the exact proportions of Hungarians, Rumanians, Germans, and Jews in each district shown on a table of statistics. The same is done for Ruthenia and Slovakia. The conclusions drawn are distinctly anti-revisionist.

The upshot of the whole work is unfavourable to Hungary. Mr. Evans goes most carefully into the cultural and economic conditions of Hungary's old minorities (Ruthenian, Slovak, Rumanian, and Slav) before and after the Treaty: and in every instance—even where the people in question still form a racial minority in the state to which they belong, as in the case of the Ruthenians —finds that there has been not merely a vast improvement; it would be truer to say that these peoples are for the first time being allowed to exist as human

beings. "A number of Hungarian political leaders, including Mr. Tibor Eckhardt," writes Mr. Evans, "have even gone so far as to say that the Hungarian peasants of Hungary would be pleased to enjoy the same rights as the Hungarian peasants of Czechoslovakia, the honest electoral system, the land reform, social insurance, etc." M. C.

ASIA

GEOLOGIE VON ASIEN. By KURT LEUCHS. Erster Band, erster Teil: Überblick über Asien, Nordasien. (Geologie der Erde Edited by ERICH KRENKEL.) *Berlin: Borntraeger* 1935. 10½×7 *inches;* viii+236 *pages; profiles and maps.* *M.*18.40

This is the first part of the Asiatic section of the *Geologie der Erde*, gradually appearing under the editorship of Professor Krenkel. Following the general plan, the author gives first a short general account of the physiography and geological composition and history of the whole continent. The rest of the present work is devoted to a detailed account of the first of the five divisions which he recognizes in Asia—North, Central, West, South, and East, thus forming essentially a Geology of Siberia. Obruchev's 'Geologie von Sibirien' is now nearly ten years old, and a new work on the subject is called for by the active researches of the geologists of the Soviet Union, as may be judged from the bibliography at the end.

Siberia is an ancient continental mass (Angaraland of Suess) consisting of pre-Cambrian metamorphics and folded Palaeozoic rocks, marine up to the Lower Carboniferous, then passing up into continental formations forming a broken sequence from Upper Carboniferous through Jurassic to Tertiary. Marine Mesozoic and Tertiary deposits are confined to the marginal regions. The main mineral wealth consists of metallic ores in the pre-Cambrian rocks and their associated intrusives, and coal in the Permo-Carboniferous, Jurassic, and Tertiary continental sediments. The stratigraphical, tectonic, and economic details are set forth in a systematic manner. A. M. D.

THE HIMALAYAN JOURNAL, Volume VII, 1935. *Oxford: The Clarendon Press.* 8½×5½ *inches;* 202 *pages; illustrations and maps.* 8*s or* 5 *rupees*

The Himalayan Journal has maintained a consistently high standard since its beginning in 1929. Volume VII is superlatively good, and should reach a public far beyond the membership of the Himalayan Club. The object of that club is "to encourage and assist Himalayan travel and exploration and to extend knowledge of the Himalaya and adjoining mountain ranges through science, art, literature, and sport." Bearing this in mind, the Editor (Lieut.-Colonel Kenneth Mason) does not confine the subject-matter to mountaineering pure and simple, but gives ample scope to survey, geography, geology, botany, and forestry; also to unambitious travel and to human contacts with the peoples of the hills.

Most welcome is the collaboration of five distinguished German scientists and mountaineers, to whom we are indebted for memorable chapters on the Nanga Parbat Expedition of 1934 and for the magnificent survey work both on Nanga Parbat and on Kangchenjunga. Two of their maps are reproduced; that of the Zemu glacier is complete and beyond praise. Mountaineers will appreciate Herr Bechtold's straightforward narrative of the Nanga Parbat disaster, which deprived many of us of valued friends, German and Sherpa.

Mr. Shipton's expedition to Nanda Devi, small in point of numbers and of expenditure but great in execution, solved a problem which had baffled man for fifty years. It will remain a standing example of what can be done by determined explorers who are also skilful mountaineers, aided by the strength and devoted

loyalty of the Sherpa porter. The stimulus of these major expeditions is apparent in the growth of interest among officers serving in India. There is an increasing number of climbs carried out during short periods of leave by men who extend their experience with each succeeding adventure and are content to begin with minor objectives. For them the Himalaya is indeed a happy playground; they are blessedly free from the incubus of "records," and they do valuable work in training local talent which will, in time, hold its own with the Sherpa. Lieut. Harrison's visit to Nun Kun is an excellent example.

Mr. F. S. Smythe contributes a valuable analysis of the problem of Kangchenjunga, confirming beyond reasonable doubt the soundness of the Bavarian attack but emphasizing the extreme difficulty of the ascent. Equally valuable is Sir Geoffrey Corbett's constructive review of 'Everest 1933.'

Interest does not in the least abate when we come to problems of geodesy, survey, erosion, earth movements, botany, and forestry. The names of Professor Finsterwalder, Captain Kingdon Ward, and Mr. Auden are a sufficient guarantee of that.

It is impossible to close this review without a tribute to the labours of the Editor himself. He has annotated every article; drawn five maps; discussed in detail (where controversy demands it, he does not hesitate to speak his mind, though without acrimony) the monumental 'Sketch of the Geography and Geology of the Himalaya Mountains and Tibet'; written three In Memoriam articles, including a detailed and well-deserved note on the Sherpas who died on Nanga Parbat; and finally contributed seven out of the eleven book reviews, and eleven pages of general notes. So long as devoted work of this kind is done, *The Himalayan Journal* will continue to hold a very high place.

It should be added that there are no less than sixty-six plates and eight maps, all splendidly reproduced. H. R.

AFRICA

MISSION AU TIBESTI (1930–1931); dirigée par M. DALLONI. [Tome] I. (Ac. Sciences Inst. France—Mém.—T.61—1934.) *Paris: Gauthier-Villars* 1934. 11 × 9 *inches;* 370 + XX *pages; illustrations and maps*

Those concerned with African—especially Central African—geology have been awaiting this publication with keen interest. M. Dalloni and his collaborators have produced a magnificent memoir, which is divided into four parts: (1) triangulation and topography, by Captain H. Simon and Captain R. Cance; (2) geography, by M. Dalloni; (3) geology, by the same author; (4) vulcanicity and lithology, by M. A. Lacroix. These sections are preceded by a short introductory history of the scientific exploration and cartography of Tibesti. The section on geodesy and topography is relatively brief, twenty pages, but it states that the geodetic party traversed 4500 km. in eight months, determined the positions of nineteen stations, and in sixteen of them carried out magnetic observations: only the most outstanding results are given, and appendices are to be published for local official use. Tables of latitude, longitude, altitude, magnetic declination, daily and annual variations, are given. The topographical section includes detailed surveys of formerly obscure districts such as Ouri, Aozou, Miski. The pioneer work of Nachtigal and Tilho in particular is fully utilized in this and all other parts of the Memoir and is co-ordinated in the regional surveys. The achievements of the two Survey officers of the Mission seems to be in inverse proportion to the small space occupied by their reports in the Memoir. M. Dalloni devotes about fifty pages to geography and eighty pages to geology: in the latter notes by specialists occupy a considerable part. The geographical

section deals with situation, communications, surface form, and climate, with detailed regional reports. The climate is naturally one of wide variety, between the torrid plains and depressions and cool mountain flanks with bitter winter weather; ancient lateritic soils are attributed to the moister Quaternary savannahs with tropical climate. The regional reports stress the geological structures and their influence upon topography, including the great volcanoes, also analyses of waters, with passing references to vegetation, fauna, and people. Numerous geological sections are given, supplemented by black-and-white sketches of the mountains and of the weird erosional forms so commonly met in these incredibly rugged massifs.

The geological section by M. Dalloni and his collaborators is a mine of priceless information which it is impossible to explore in a brief review: readers of the *Journal* who are concerned with African geology must read the Memoir for themselves. Among many subjects considered in detail and beautifully illustrated in the plates are the imprints found in the Silurian sandstones, the fossil *Dadoxylon* wood of Aozou, Quaternary diatoms, and fossil fish and reptiles. M. Dalloni's personal contribution to Central African tectonics, both pre-Cambrian and recent, included in this Memoir, is both fascinating and of great importance.

The final part, by M. Lacroix, deals exhaustively with vulcanicity and lithology, and occupies nearly 200 pages: it is a magnificent contribution to African petrology by a master of the subject. About half the space is given to detailed and descriptive petrology and analyses of the rock-types, and the remaining half is devoted to a comprehensive and comparative study of allied types of the French Sahara, the Chad region, Libya, the Egyptian deserts, the Sudan, Abyssinia, East Africa, etc., and of the Red Sea and Arabia. Some crucial notes on the age of certain granitic rocks are included. In this *Journal* it is impossible to do more than hint at the supreme importance of M. Lacroix's monumental contribution and at its many new issues, geological questions, and deductions. There is a detailed topographical map on the scale of 1 : 1 M, and a geological map of 1 : 2 M, both of them marking a profound advance in the cartography of the region: unlike some continental maps, they are printed on a strong paper that is worthy of them.

The Memoir is a lasting memorial to French endeavour in a formerly remote and dangerous part of their territories; before the book even reached this Society's library a considerable area of the region in which M. Dalloni and his countrymen laboured had been ceded to Italy. K. S. S.

L'ETABLISSEMENT D'ISSINY, 1687–1702. By PAUL ROUSSIER. Voyages de Ducasse, Tibierge et d'Amon à la Côte de Guinée . . . suivis de la Relation du Voyage du Royaume d'Issiny du P. GODEFROY LOYER. (Publications du Comité d'Etudes Historiques et Scientifiques de l'Afrique Occidentale Française. Sér. A. No. 3.) *Paris: Larose* 1935. 10×6½ *inches;* xl+242 *pages; illustrations and chart.*

It is an article of faith in France that Frenchmen were trading from Cape Verde to the Gold Coast in the fourteenth century, and that they had an establishment at Elmina one hundred years before the Portuguese built their fort there in 1482. Mr. Claridge has shown that, so far as these claims rest on a basis of native tradition, they cannot be lightly dismissed; but for the existence of a prehistoric French factory at Elmina great reliance is placed in the discovery of a stone in the fort incised with a date, partly illegible, but assigned to the fourteenth century. It must be borne in mind however that the mere fact of the letters MCCC being legible does not prove that the date was cut in the fourteenth

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This however proved impossible. War against England and Holland broke out; and though at the outset France had some flicker of success at sea, yet in 1693 the Anglo-Dutch victory at Barfleur ruined her hopes. Thus a voyage in 1692, of which we have some account from Tibierge, chief supercargo of the Guinea Company; another begun in 1698, during the short peace which followed the treaty Ryswick, and its sequel in 1701–02, represent the sum of what France was then able to undertake officially on the Gold Coast. These last-named voyages were commanded by the Chevalier D'Amon, who in the second of them built and manned a small fort at Issiny, a very small "kingdom" and especially friendly to the French. Such friendship was apt to recoil on the heads of its professors. In 1702, as soon as D'Amon's ships were out of the way, the Dutch attacked the new fort, but, chiefly owing to efficient help from the Issinians, were badly beaten off. This however led to no development of the infant factory which, left hopelessly to itself, was at starvation point two years later, when fortunately a French trader came in and summarily removed the few survivors. The French project at Commando advanced as far as the securing of a concession for building a factory; but the Dutch cut off the head of the king of Commendo, and the project lapsed.

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NORTH AMERICA

CANADA, TO-DAY AND TO-MORROW. By BASIL FULLER. *London: Stanley Paul & Co.* [1935]. $9\frac{1}{2} \times 6$ *inches; 288 pages; illustrations.* 15*s*

In this book Mr. Basil Fuller has given one of the best accounts yet published of conditions as they exist in the great Dominion to-day. He has visited all the provinces and mixed with all sorts and conditions of men, and many of his stories give vivid pictures of the present-day conditions. The language however which he puts into the mouths of the people he meets is very much overdone.

All Canadians don't call strangers "brother," nor do we speak of pebbles as "rocks." From Mr. Fuller's book one would think all Canadians were "Hickies," and were totally uneducated.

He rightly draws attention to the increase in the French-Canadian population, but this is nothing new; it has been going on for many years, and families of twenty and twenty-five have been common. The *habitant* certainly does not speak the language of Jacques Cartier, who by the way never visited Hochelaga in 1534, nor did he ever, as stated, erect a cross on Mount-Royal. Educated French-Canadians speak excellent French.

His references to the United Empire Loyalist Immigration and to the Americans' idea of sport are quite true and certainly account in part for the Canadians' feelings towards the Americans.

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Mr. Fuller sees hope for Canada in her rich gold deposits and her output of petroleum, and one hopes that his forecast will prove true. Canada certainly possesses the richest deposits of gold and silver in North America. Canada also possesses many good pictures by old masters in her many galleries in spite of Samuel Butler's satirical poem upon that of Montreal. *Coureurs des bois* should be *de bois*, and Rockingham Park on p. 189 should surely be Rockcliffe? The illustrations are very good. H. P. B.

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The phenomenal modern development of Los Angeles is to be attributed mainly to a remarkable combination of chance, haphazard growth, and far-seeing private and co-operative enterprise, in the exploitation of its natural resources and the conquest of the disadvantages inherent in its physical setting. To this development Advertising and Speculation are the key notes. "Die Millionstadt Los Angeles ist ein künstliches Produkt, das die U.S. Amerikanische Psyche zur Voranssetzung hat" (p. 159). This is the guiding concept of the author (p. 9). It determines the plan of his work which is arranged in five sections: the physical setting, changes of landscape before the first boom, settlement origins, great city formation, the life and form of the present urban landscape.

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loyalty of the Sherpa porter. The stimulus of these major expeditions is apparent in the growth of interest among officers serving in India. There is an increasing number of climbs carried out during short periods of leave by men who extend their experience with each succeeding adventure and are content to begin with minor objectives. For them the Himalaya is indeed a happy playground; they are blessedly free from the incubus of "records," and they do valuable work in training local talent which will, in time, hold its own with the Sherpa. Lieut. Harrison's visit to Nun Kun is an excellent example.

Mr. F. S. Smythe contributes a valuable analysis of the problem of Kangchenjunga, confirming beyond reasonable doubt the soundness of the Bavarian attack but emphasizing the extreme difficulty of the ascent. Equally valuable is Sir Geoffrey Corbett's constructive review of 'Everest 1933.'

Interest does not in the least abate when we come to problems of geodesy, survey, erosion, earth movements, botany, and forestry. The names of Professor Finsterwalder, Captain Kingdon Ward, and Mr. Auden are a sufficient guarantee of that.

It is impossible to close this review without a tribute to the labours of the Editor himself. He has annotated every article; drawn five maps; discussed in detail (where controversy demands it, he does not hesitate to speak his mind, though without acrimony) the monumental 'Sketch of the Geography and Geology of the Himalaya Mountains and Tibet'; written three In Memoriam articles, including a detailed and well-deserved note on the Sherpas who died on Nanga Parbat; and finally contributed seven out of the eleven book reviews, and eleven pages of general notes. So long as devoted work of this kind is done, *The Himalayan Journal* will continue to hold a very high place.

It should be added that there are no less than sixty-six plates and eight maps, all splendidly reproduced. H. R.

AFRICA

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while invalids and tourists were attracted by the reputation of its climate (1865–85).

Unrestricted railroad competition led to the first (land) boom in the 'eighties. The second boom (1900–14) was characterized by the rapid extension of the built-upon land, the general plan of which was due to the enterprise of one individual, H. E. Huntington. The third boom (post-war) largely assisted by the automobile, witnessed the filling up of the intervening unbuilt-upon areas. In this same period came the prodigious development of the film and oil industries which radically changed the appearance of the landscape and introduced new psychological and social elements.

To permit the future growth of the metropolis, the Chamber of Commerce had two great problems to solve—water supply and port facilities. Underground water supplies soon were inadequate, and between 1908–13 an aqueduct 350 kms. long was constructed to convey water from Owens Valley. To meet future needs an even greater scheme is under way for the conveyance of water from the Hoover Dam. To take advantage of the opportunities afforded by the Panama Canal, the Chamber of Commerce undertook the construction of an entirely artificial harbour at San Pedro. This was opened at the same time as the Canal, and owing to the subsequent development of the oil industry, ranks second in tonnage among American ports.

The work is well illustrated and contains an exhaustive bibliography with some 800 references. There are twenty maps. Some of these however are generalized, and particularly in the latter half of the work one felt the need of good maps of landscape data. Fig. 14 is the only map of this type and it could have been greatly improved. While the sociological interpretation of city growth of Park and Burgess is presented (p. 211), there is no mention of the contributions of American geographers to the problem of the cartographic representation of urban forms. It is remarkable that the author has not used the special census volume of Los Angeles with population statistics for every census district (see population map of Chicago by reviewer in 'La Vie Urbaine,' January 1934). It could have served as a basis for a number of population maps to illustrate his appropriate sections. The bibliography is not well handled. Many references are obviously quite valueless, and of the very few references in the text several are not listed (*e.g.* p. 172).

Apart from these criticisms the book is interestingly written and is an important contribution to urban geography. R. E. D.

CENTRAL AND SOUTH AMERICA

DESOLATE MARCHES: Travels in the Orinoco Llanos of Venezuela. By L. M. NESBITT. *London: Jonathan Cape* 1935. $8 \times 5\frac{1}{2}$ *inches; 320 pages; illustrations and sketch-map.* 10*s* 6*d*

It is unhappily necessary to begin this review with a reference to the untimely death of the author, who was killed in an accident to a passenger aeroplane on July 21. Mr. Nesbitt became known to the Society by his long and striking paper on "Danakil traversed from South to North in 1928," published in three parts in the *Geographical Journal* for October, November, and December 1930 with many excellent panoramic sketches made by him on an arduous journey with two Italian companions. For this he received the Murchison Award of the Society in 1930; and a book on the same journey 'Desert and Forest,' recently published in England, but following an earlier book in Italian, has in the circumstances of the time achieved a considerable success. Before the Abyssinian journeys however Mr. Nesbitt had worked, as he says in the "Desolate Marches,"

for four years in different parts of North and Central America. This period of American work ended with the survey made, in the early part of 1927, in a small section of the plains of the Orinoco delta, for a company interested in petroleum fields. He entered Venezuela, as most travellers first enter this country, by way of La Guaira; thence followed the excellent military road to Caracas, and from that valley city went by car from the mountains towards the flat country due south.

This region, as those of us who have chanced to enter it from the Orinoco's mouth are aware, is flat, often swamped, and covered in vast patches with lush-tangled forest; there are but a few months when such work as surveying can be profitably undertaken. It was therefore in the middle of January (1927) when Nesbitt left the 4000-foot-high region of Caracas among the mountains and made his way through a wild country of which he was not fated to receive flattering impressions. For, apart from fever, dysentery, poor food, bad water and living accommodation, Nesbitt seems to have received a distinct idea that the Anzoategui region had deteriorated in productive power and population since Spanish times. The only bright spots were apparently the kindly hospitality of isolated dwellers in the Llanos, where "the old towns and farmsteads of the Spanish crumble slowly back into the earth." In all the thousands of miles covered during his work, the largest town was that not-too-well-supplied centre, Barcelona, generally reached by sea from La Guaira.

The author's sketches of scenery and regional map are useful and illuminating, and the style is vivid, as in his earlier writings. The index is inadequate and not infrequently misleading by its omissions; and, although Venezuelan place-names are almost invariably correct, the proof reading is not always worthy of Mr. Nesbitt's text. One understands that the author himself, having lived long in Italy, may have written "spargate" instead of the Spanish word for the same sort of sandals, "alpargata"; but such an explanation does not account for a place-name occurring as "Marapaca" and "Maparaca" on the same page (273). He was not well served by the reader for the press. L. E. J.

PHYSICAL AND BIOLOGICAL GEOGRAPHY

GEOGRAPHIE DES INDISCHEN UND STILLEN OZEANS. By GERHARD SCHOTT ("im Auftrage der Deutschen Seewarte"). *Hamburg: C. Boysen* 1935. 11 × 7½ *inches;* xx, 414 + XXXVII *pages; illustrations and maps. M.*36

Gerhard Schott has long been known as one of the foremost authorities on oceanography. It is but a few years since the second edition of his 'Atlantic Ocean' was published. He has followed this with the present work on the Indian and Pacific Oceans. Dr. Schott does not, perhaps, know those two vast areas so well as he does the Atlantic, but he has nevertheless produced a monumental work which will be of the greatest service to students the world over. It is also relevant to point out that it is a *Geography* of the oceans, and that, in consequence, it is of wide appeal to workers whether on the physical or other sides of the problems presented by these oceans. However far greater stress is laid upon the physical aspect.

The maps form a comprehensive atlas. They are all of them coloured plates, for the most part double-page, and there is one larger folding-map of the configuration of the sea-floor. The projection used is a world development of a form of Lambert's Equal Area Zenithal, and is very suitable for the purpose. The maps are very clear and not confused with too much detail. They include representations of air temperature and pressure; salinity and temperature in the oceans

both at the surface and at different depths; bottom deposits; general regional geology and tectonics, including earthquakes and volcanoes; sailing and steamship routes; voyages of discovery and of scientific expeditions; and other features, *e.g.* cable-lines and radio-stations, etc. No such complete series exists elsewhere, and the maps alone are in themselves more than sufficient reason for the inclusion of the volume in any geographical library, whether school or university.

Before discussing certain matters which arise from the text, it may be useful to give briefly a synopsis of the contents under chapter headings. They include: The main voyages of discovery; The research voyages; Names, boundaries, extent, and divisions of the oceans; Geological and tectonic relations; The ocean floor and deposits; Oceanographical and meteorological phenomena of the surface waters; An analysis of the deeper waters—their temperature, salinity, gas content, and circulation; The natural regions of the oceans (two long and useful chapters); Life in the oceans (by F. Hentschel); and finally a chapter on the "works" of man, ranging from the early voyages of native peoples to radiotelephony!

This in itself shows that here, in reasonable compass, is an account of these two oceans such as does not exist in any other language. The material is skilfully handled, and it is easy to refer to particular problems. Naturally, any such comprehensive work cannot treat all subjects in a specialist way, and the author's task must have been made more difficult in deciding what to omit. An instance arises in connection with coral reefs. The author is clearly concerned more with their distribution and purely geographical aspect than with theories. Yet, for all that, it seems rather a pity that the only theory dealt with at all—and even that in bare outline—is Darwin's. Granted that there has been a marked swing of the pendulum back to this theory in recent years, it nevertheless seems to the reviewer that some mention should have been made of glacial control, for it is practically certain that sea-level oscillations during the ice-age had a great effect on reef growth—as well as on other coastal and oceanic phenomena. In fact, Daly's name is omitted. Again, in discussing the north-east monsoon, the author apparently does not consider the work of certain Indian meteorologists (*e.g.* Eliot) in suggesting that the rains in south-east India and north-east Ceylon are connected rather with the retreating south-west monsoon than with the north-east monsoon. This may be a matter yet to be settled, but it is a pity that some discussion is not included in the present volume. So far as the reviewer is aware the "orthodox" views as expressed in this book still hold good, but a decisive statement would have cleared up certain doubts which may still exist.

One excellent feature of the work is the inclusion of very representative bibliographies at the end of each chapter. These are by no means wholly confined to German authorities. The text-figures are well reproduced, and the whole appearance of the book is excellent. Plate 35 and the relevant part of the text deal with the nature and distribution of deep-sea deposits. The difficulties of making such a map are obvious, but there are certain fundamental ways in which it differs from the current maps in most English text-books. For example, the long stretch of the ocean floor running westwards from America in the equatorial region is usually shown as covered by radiolarian ooze. Schott's map shows this part under globigerina ooze, whereas radiolaria, *sensu stricto*, are confined to three distinct areas—the first about 10° N. and between 90° and 100° W. long.; the second (and largest) between about 6° and 14° N., and 134° and 160° W.; the third is roughly bisected by the Equator between the 160th and 170th meridians of West longitude. Other differences will be clear if the map is studied carefully.

The large bathymetric map brings out certain features very clearly. Especially noteworthy are (1) the South and East Pacific "Schwellen" running into the Albatross Plateau. This great composite ridge-plateau runs from South Victoria Land *via* Easter Island to the Galapagos Islands and Mexico. The greatest breadth is roughly on the latitude of Easter Island; (2) in the Indian Ocean is another comparable feature running south-east from Sokotra, where it is joined by a second branch trending south from the north and east part of the Arabian Sea. The two then join, continue to the south, uniting the Chagos and Mascarene ridges, and run *via* New Amsterdam and St. Paul to the Kerguelen ridge and so to the Antarctic Continent. Some comparison of these two great features with the Central Atlantic ridge is made in the text.

Oceanic circulation of surface and deep waters is treated at some length—a matter which might well be considered more fully in English text-books. The author follows the usual modern scheme and differentiates sub-tropical water, sub-antarctic water (*i.e.* Mischwasser mittlerer Breiten), and antarctic water. The first and second are separated by the subtropical convergence; the second and third by the sub-polar convergence. In the Pacific there are also convergences north of the Equator, but the narrow and shallow connection *via* Behring Straits with the Arctic Ocean necessarily prevents a symmetrical development such as is postulated in the Atlantic Ocean. The old, simple ideas of vertical circulation have given place to new ones based on the analysis of temperature, salinity, and gas content at various depths. This analysis suggests that there are great masses of water moving more or less horizontally beneath the surface, and that they have entered into these regions from the surface where they sank as a result of Archimedian forces. In fact, as Schumacher has pointed out, the phrase "vertical circulation" now really means the movement of deep-lying waters which can be detected by means of vertical sections—and it is important to remember the great exaggeration of the vertical scale in these sections which is necessary to show the different layers of water. A series of interesting and useful tables is also given, and these help to bring out the importance of temperature inversions and salt content of the several water layers.

The geographer will find a great deal of other material of direct interest. As noted earlier, the book certainly has a strong physical bias, but the economic and even the historical geographer will find matters of interest. The whole work shows clear evidence of careful planning and it is very up to date—reference is frequently made, *e.g.* to the recent Dutch Snellius Expedition, whose reports are still being published. J. A. S.

GENERAL

MEMORANDUM ON THE TEACHING OF GEOGRAPHY. Issued by the Incorporated Association of Assistant Masters in Secondary Schools. *London: George Philip & Son* 1935. $7\frac{1}{2} \times 4\frac{1}{2}$ *inches;* xvi + 418 *pages; illustrations.* 7*s* 6*d*

This volume follows a series of Reports, on the teaching of various subjects in secondary and public schools, which have been issued by the Incorporated Association of Assistant Masters, and the issue marks a stage in the evolution of the teaching of geography. While the context of the subject is still undefined the broad principles of modern causal study have been delimited, and there also exists a supply of teachers who possess a university training in geography as well as pedagogic qualifications. In response to the pioneer work of leaders as Dr. Mill and Dr. Newbigin the attitude of educational authorities has altered, and now geography plays a large part, as an optional subject, in the various

school certificate examinations. This last control is irksome to the teacher and there is a useful chapter of valuable critical comments. A full analysis of the new system of examining adopted by the Northern Universities Joint Matriculation Board is given and analogy made with other methods of testing the capabilities of scholars and, it may be added, teachers.

That the shadow of examinations lies heavily on the teachers may be seen in a statement of the page lengths of the principal chapters: "Scheme of Work," 69; "Teaching Methods," 95; "Equipment," 50; "Sixth Form Geography," 32; "Examinations," 50; and "Geography outside the Time Table," 21 pages. These chapters are preceded by two short ones on the position and scope of the subject in schools and followed by one on the cultural relations. A most valuable feature of the volume is the set of appendices: sources of teaching equipment, bibliography, careers for scholars, and how a geography camp was run are among the topics dealt with. The volume has been well illustrated by means of photographs and line blocks, and these fall into two main categories—firstly those which illustrate layout and equipment of the geography room, and secondly, illustrations of use in lessons. These take the form of episcope or blackboard diagrams. In connection with the latter the blackboard summary map on p. 122 appears to the reviewer to be too complicated for its function, even with initials for names, and seems to be usurping the more appropriate use of an atlas.

The Committee of the I.A.A.M. are to be congratulated on producing such a handbook which will be a *vade mecum* for all geography teachers and so help to raise the general level of teaching the subject. The volume has succeeded in being readable despite the irritating paragraph numbers in bold type.

A. C. O.

ADVENTURES WITH ANIMALS AND MEN. By CHERRY KEARTON. *London: Longmans, Green & Co.* 1935. 9×5½ *inches;* xvi+292 *pages; illustrations.* 12*s* 6*d*

Mr. Kearton's latest book impresses one as having been written from memory long after the events which it chronicles had taken place, and in the lapse of time the tale loses much in the telling. It is, in reality, a recital of hairbreadth escapes in which the author is always the hero. An animal photographer in the days of which he is writing, 1909–14, undoubtedly had to take his life in his hands, and all praise is due to one who could in those days become master of his art. Animal lovers, and those who wish to see our "big game" preserved for posterity, will owe Mr. Kearton a debt for having shown that hunting with a camera can supply just as many thrills as hunting with a rifle and incidentally be just as profitable. His condemnation of faked animal films, with the all too frequent accompaniment of cruelty, will have the support of all sporting cinema-goers. On this subject the author plainly speaks with authority, and he should be called into consultation by those whose duty it is to judge of such malpractices. The author's evident sympathy with wild animals is the best part of the book, but it is a pity that Mr. Kearton's engrossment in telling of his exploits and daring is such as to shut out much else. Those who wish to read of the more intimate side of the creatures' lives will prefer 'The Animals came to Drink' to the volume under review. Most of the adventures took place in Africa, where Mr. Kearton was a pioneer photographer in pre-war days. In his last chapters the author gives his personal reminiscences of Flanders and East Africa during the early days of the war. The book is printed in large type and is illustrated with some good photographs. A misprint appears on p. 139 where the Aruwimi river is mis-spelt Aremwimi.

D. A. B.

THE MONTHLY RECORD

PARK AND LANDER AT BUSSA

In the *Journal* (vol. 75, p. 96), reference is made to a despatch from Mr. W. Hamilton-Browne, Resident of Kontagora, to the Secretary, Northern Provinces, communicated to the Society by the Secretary of State for the Colonies, who had received it from the Governor of Nigeria (*Journal*, vol. 57, p. 130). In this despatch it was suggested that the silver medal of George III, which is one of the insignia of the Emirs of Bussa, was originally presented to an ancestor of the present Emir by Mungo Park. The Society has now received the following note from Major W. H. Wilkin which makes Lander a more probable donor than Park.

Hastings ('Voyage of the *Dayspring*,' p. 172) gives a photograph of the Chief of Bussa "wearing medal ring given by Mungo Park." He describes the medal as follows: "a large silver medal three inches in diameter, with the head of one of the Georges on one side and the royal arms on the other." He adds that the Chief said that the ring had been given to his grandfather. I think there can be no doubt that this medal was not given by Mungo Park at all.

Lander ('Discovery of the termination of the Niger,' vol. 2, pp. 103–104) says that on Friday 6 August 1830 "we thought proper to present him (The Chief of Boussa), in the name of our sovereign, with one of those beautiful silver medals which were cast during the American War, for the purpose of distributing amongst those Indian chiefs who were favourable to the English interests. A large and valuable chain of the same metal was attached to it, and nothing which we had previously given the king seemed to have pleased him so much as this medal and chain; he regarded it indeed with childish admiration."

This Indian Chiefs' medal, 3 inches in diameter, bears on the obverse the bust of King George III under the legend—*Georgius III. Dei Gratia Brittannarum Rex F.D.*"; and on the reverse the royal arms, with the date 1814 in the exergue.

Two other medals were struck for the Indian Chiefs, but the medal described above was the only one that bore the royal arms on the reverse. Doubtless this medal, presented by Lander, is the one now worn by the Chief of Bussa on a ring.

VOM DEUTSCHEN OSTEN

On the occasion of the sixtieth birthday of Professor Max Friederichsen in 1934 a volume of studies was published by the Silesian Geographical Society and the Geographical Institute of the University of Breslau under the title of 'Vom deutschen Osten.' The object and the spirit actuating the contributors are made plain in the first essay, in which Dr. H. Schlenger examines the relations between cultural geography and German ethnology in the east German area. In a regional study, he argues, there is something more required than an examination of the natural conditions and the present cultural phenomena: a third factor enters in, a "spiritual component," deriving from tradition and history, which has been introduced by man, in this case the bearer of German culture from the west. By examples drawn from the 'Atlas der Deutschen Volkskunde,' he shows how the east has been linked in the past to the German state, how boundaries which have long disappeared, for example the medieval German–Slav frontier, have left their mark culturally. This is the former theory of the 'Drang nach Osten' from a new standpoint. The studies which follow drive home this point. The 'Deutsch Ost' is not defined, but it comprises at least the area within the pre-war boundaries. Thus Geisler examines the settlements of the

lower Vistula basin to prove that the initiative in their foundation was German: a historian maps the extent of the prevalence of German town codes in Eastern Europe, and other writers emphasize the role of Silesia as a corridor of German influence and its essential unity with the nation, and describe the fluctuating fortunes of Silesian migration beyond the province. Somewhat incongruously after a score of essays on these lines come half a dozen studies dealing with questions of geology and physical geography. For those wishing to appreciate the present trend of German studies in Eastern Europe, this "Festschrift" provides a compact and significant guide.

THE HISTORY OF CARTOGRAPHY

The first number of a new periodical dealing with historical cartography, entitled *Imago Mundi* (Berlin 1935), contains an article by Richard Uhden on "Die antiken Grundlagen der mittelalterlichen Seekarten." The main argument, supported by extensive references to original sources and recent commentators, is that the portolan charts of the early fourteenth century were not isolated phenomena, unrelated to earlier developments, but that sea-charts were in use from classical times onwards, and a style of chart resembling the portolans would have developed, without the introduction of the compass. Classical authors, principally Strabo and Agathemerus, are quoted as evidence for the existence of sea-charts, and from instances in Pliny where courses and distances are given in a form resembling a portolano, it is argued that he was using a classical pilot book. The question of direction is treated with reference to the wind-rose of Timosthenes, based upon a twelve-wind system, which was employed throughout classical and medieval times. This system of orientation is employed in the work of the "anonymous geographer" of Ravenna, who is held to have had a sea-chart among his authorities, the title of which may be reflected in a phrase employed—"totius mundi portus et promuntoria." The text also embodies a portion of a pilot book. Ravenna was for a time a base for the Byzantine fleet, so that much similar material would be available for the anonymous geographer. The wind-rose, for the descriptions in the text, was centred at Ravenna; on the sea-chart it was apparently centred in the Cyclades. The author seemingly believes that the lines radiating from the rose were the origin of the loxodromic lines.

Thus, in his opinion, none of the characteristic features of the portolans of the fourteenth century were new: well drawn, coloured, and richly decorated, they owed more to the contemporary renaissance of Italian art than to the introduction of the compass, and were intended for gifts rather than for use at sea. They were, like their forerunners, plane charts, based upon data of direction and distance; their superiority was due merely to the accumulation of material throughout the centuries. It seems however difficult to deny to the compass an influence in increasing the accuracy of the portolans.

A very similar plea for the recognition of the continuity of cartographic development from classical to renaissance times is made by Professor A. Mori in a paper "Osservazioni sulla cartografia Romana in relazione colla cartografia Tolemaico e colle carte nautiche medioevali," reprinted from the *Atti* of the Third National Congress of Roman Studies. Though no true geographical maps have survived from the Roman period—for the so-called Peutinger Table was a "practical" diagram similar to some modern types of railway maps—the author argues that the Roman cartographical contribution was considerable. The cadastral work of the "Gromatici" was capable of being co-ordinated upon a framework provided by the road system to form a map of the Empire, such as the *Orbis pictus* initiated by Agrippa and completed under Augustus.

Evidence is also given to show that topographical surveyors accompanied many military expeditions in distant parts of the Empire. The author believes that from these two sources Ptolemy obtained much of his material, for it is now generally recognized that comparatively few of his positions were determined by observations. The makers of the early portolans also drew upon this material, which explains their superiority over the contemporary "mappamondi," as did the authors of the early topographical maps which appeared in Italy in the fifteenth century, *e.g.* the map of Italy found in the 'Cronaca of Fra Paolino,' and the *tabulae novae* which were added to the maps in Ptolemy's 'Geografia.' Professor Mori also believes that the characteristic net of reference lines upon the portolan charts was derived from the technique of the "Gromatici."

NOTABLE ANTARCTIC VOYAGE OF THE BARQUE *VENUS*

It is not generally known that an Australian whaling vessel had penetrated to 72° of south latitude in the neighbourhood of the Ross Sea some nine years before Sir James Clark Ross' famous voyage. This however appears to have been the case, as indicated by records now in the Mitchell Library, Sydney.

R. McNab, in his book 'Old Whaling Days,' refers on p. 88 to this voyage of the *Venus*. The chief evidence is contained in a letter formerly in possession of Dr. W. N. Crowther, of Hobart, now deposited with the Mitchell Library in Sydney. This communication is addressed by the Master of the *Venus* to the owner, Mr. J. Kelly, of Hobart Town. It is dated 23 January 1832, and reads as follows:

An opportunity offering I thought you would have no objection to hear how I got on in my Southern Speck.

After leaving Mc.Island I proceeded as far as 72° South, but with a succession of fogs and thick weather it was utterly impossible to see further than a mile from the ship the whole time.

Macquarie's is entirely cut up, I landed at both ends of the Island but could see no signs of an elephant whatever.

I put into Campbell's Island to set up casks etc. for whaling, here I procured 170 prime skins. I put ashore at the head of Perseverance Harbour about 20 tons of salt and burnt it over, it would pay a boat crew to remain there.

I next proceeded to Cloudy Bay, where I got 140 tons of oil, and we had a taste of the Sperm Gentlemen on my passage up. I have landed here—

140 tons Whale Oil
6 ,, Whalebone
25 ,, Sperm Oil
170 ,, Skins

and am now fitting out for the Sperm Fishing, I hope to be away in a month from this.

(Signed) Samuel Harvey.

Further information is recorded in the *Australian* of period 1830–1835. It appears that the *Venus*, a barque of 288 tons, left London on 17 June 1830 and reached Hobart Town on November 20. She sailed on the whaling and scaling cruise mentioned in the above letter on 9 January 1831 and arrived in Sydney at the conclusion of the voyage on December 31 that same year.

Starting from Macquarie Island, penetration to 72° south latitude must have brought them somewhere in the vicinity of the entrance to the Ross Sea.

As Captain J. Kelly, the owner, was Harbour Master of Hobart Town, he doubtless came into close contact with Ross on the arrival of the *Erebus* and *Terror* late in 1840. Consequently, Ross prior to departure south was in all probability aware that vessels could penetrate to at least 72° south latitude in the region south and east of Macquarie Island; whereas, where Wilkes and D'Urville had sailed the previous season they had been unable to reach even to the Antarctic

Circle. This knowledge therefore may have influenced Ross, to some extent, in deciding to set a course in that direction. D.M.

ANOTHER LAFRERI ATLAS

The appearance in Sotheby's sale-room, in the second week of December last, of a fine set of the early Italian maps known as 'Lafreri's Atlas,' adds yet another to the known copies of this famous collection, preserving probably the form in which they left Lafreri's shop in the sixteenth century. The number of items in the present set is smaller than in some—107 as against the 160 of the Madrid example, described by Dr. F. C. Wieder in 1915, to compare it with one which is not merely a collection brought together more or less at haphazard. But the absence of extraneous items and the fact that no map or plan bears a date later than 1566, give reason to think that the set really deserves the name of a Lafreri Atlas. It is true that it lacks the scarce engraved title-page, but this appears to have been supplied somewhat later, after a good many sets had been sold without it.

Further support for its original character may be found in the fairly close agreement, as regards contents and the states or dates of issue of the separate maps, with the "Wyld" copy owned by the Society since 1919, and fully described in the *Journal* for April of that year. It is true that there are a good many differences. Thus the Wyld copy has the title, and one or two maps later than 1570, while it lacks some of the items of the set now brought to light—a few of which are distinctly rare. Such is the large world-map in hemispheres published by Tramezino in 1554—each hemisphere in two sheets joined—which is not often found complete, though both hemispheres occur in the collection formerly at Trieste and now in the G. H. Beans Library in Pennsylvania, and both were reproduced as early as 1894 in F. Muller and Co.'s 'Remarkable Maps' from copies in the Bodel-Nyenhuis collection at Leiden. Smaller, and less rare, is Gastaldi's world-map of 1560, on the oval pseudo-projection also used by Ortelius, of which a copy bearing the same date is in the Wyld collection (one of 1562 was reproduced by Nordenskiöld in his 'Periplus'). The first item in the set is the "Floreanus" world-map in a double series of radiating gores for a globe, which the Society possesses in the "Peckover" copy of the Atlas, and the earliest map proper is Gastaldi's Sicily of 1545, also in the Peckover set.

The relatively early date of the present collection (as also of the Wyld copy) is supported by the presence of maps of various parts of Western Europe, particularly the Netherlands, brought out by Tramezino in 1556–58, but more often seen in later issues. Agreement with the Wyld volume is also shown by the presence of Tramezino's map of Germany of 1553, bearing what may be taken as the *imprimatur* of George Lily, also seen in the British Isles of 1546. This last is not in the present set, but, as in the Wyld set, is represented by the issues of 1556 and 1558. Both sets also have the somewhat rare Portugal by Statius (1561) and the Palestine of Della Gatta (1557), while in both the map of the lower Danube is in its early state, before the name of Lafreri was added. Many of the other maps are commonly found in the Atlas—such for example as Gastaldi's fine maps of Asia in three sections, and Forlani's of Africa and South America, as well as the rather crude small maps of islands. The general agreement between the two sets here compared might suggest that these copies of the Atlas were made up by Lafreri from stock available at the dates of sale, rather than at the special order of customers.

One would like to know more of the past ownership of copies of the Atlas, particularly whether any have been continuously in English hands since early days. The present copy has not, for on inquiry of its late owner, Dr. Philip

Turner, of Liss, Hants, we learn that it was bought by him from a bookseller at Barcelona. Although the margins added to the smaller maps to bring them to the required size, have the appearance, mostly, of contemporary paper (few watermarks were observed on a somewhat rapid inspection) the binding is modern, put down as of about seventy-five years ago. It is of half-red morocco and the front cover bears the letters F.V., while the back bears the title "Forlani-Atlas, 1545–1566." Most of the maps are in remarkably clean condition.

THE FORMOSA EARTHQUAKE OF 21 APRIL 1935

This destructive earthquake has been studied by Japanese seismologists and their reports will appear in a special volume of the Bulletin of the Earthquake Research Institute. In the meantime, two preliminary reports have been published, one by Mr. R. Takahasi in the *Proceedings of the Imperial Academy*, vol. 11, pp. 224–226, the other by Mr. T. Suzuki in the *Japanese Journal of Astronomy and Geophysics*, vol. 13, pp. 55–59. The earthquake occurred at 7.2 a.m. on April 21 (or 10.2 p.m. on April 20, G.M.T.). In the two north-western prefectures of Sintiku and Taityû, the destruction of houses, for the most part built of sun-dried mud blocks, was almost complete, more than four-fifths of the houses being ruined in a narrow zone directed north-north-east, more than 40 miles long and less than 10 miles wide. According to the report of the Government-General of Formosa, 1428 persons were killed in the prefecture of Sintiku, and 1982 in that of Taityû, 17,907 houses collapsed, and 21,211 were seriously, and 15,570 slightly, damaged. Within the zone of destruction, the crust is rent by a series of small faults. Of the two more important, one, in the south-west part of the area, is about 6 miles long, the north-west side, relatively to the other, being shifted 4 feet 8 inches to the north-east and depressed 1 foot 7 inches. The other, in the north-east of the area is of about the same length, but is a thrust fault inclined at 70° to the vertical, the west side being raised relatively by from 8 to 10 feet without appreciable horizontal displacement. The region between these two faults is traversed by several minor rents. It also contains the epicentre determined by seismograms obtained at Tokyo and at several stations in Formosa as lying in lat. 24° 21′ N., long. 120° 49′ E. Mr. Suzuki estimates the maximum acceleration of the vibrations as less than one-third of that due to gravity, and considers that the earthquake, though of such destructive power, was of less intensity than two recent Japanese earthquakes, those of Tango on 7 March 1927, and the Idu Peninsula on 26 November 1930.

C. D.

GEOLOGICAL OBSERVATIONS IN N.W. SUDAN

By making his own extensive field work with Major R. A. Bagnold's Expedition of 1932 the basis of a regional correlation of other scattered results, Dr. Sandford, writing in the *Quarterly Journal of the Geological Society*, xci (1935), has produced a considerable addition to the geological map of Africa. His main contributions to the geology of the area are (1) the separation of the "Nubian Series" (not later than Cretaceous) from other sedimentary series which are much older; and (2) the description of widespread, post-Nubian craters, plugs and lavas, some of which are undoubtedly young. By combining a series of radial traverses from 'Uweinat with a radial series of sectional analyses from a selected, "central" area east of 'Uweinat, he has been able to deduce the elevation above sea-level, and the slope, of the Archaean basement complex, and so to estimate the thickness of its cover of Nubian rocks. The sections which accompany the map are somewhat modestly drawn. The evidence of unconformity between the Nubian and the Palaeozoic series and of post-Nubian faulting

given in the text is convincing, but it is not made to appear so in the sections. This is regrettable in sections so likely to be copied or reprinted. Petrologically, the region may become one of classical importance. It records a history of so-called "alkaline" intrusion in early, and extrusion in late, geological time. Considering the almost complete absence of limestones from the Archaean complex, and the thinness of the sediments which now cover it, the conclusions that the igneous rocks are what Washington calls "comagmatic" and that they are uncontaminated by the assimilation of alkaline sediments, seem inevitable. If so, the conditions presented for the study of alkaline rocks are unique. The solution of a problem of existing topography may prove however that they are less simple than they appear to be. Masses of plutonic rock, believed to be pre-Cambrian and known to be pre-Nubian, show through the Nubian series like the fossil *Inselberge* of a pre-Nubian, desert landscape, and still rise, in places, as at 'Uweinat, 1500 feet above the surrounding country. Their original exposure implies the removal of a tremendous thickness of material of which, it seems, no trace remains; and why they were not reduced to the general level of the basement complex before or during Nubian time is not yet explained. Dr. Sandford's diagram of the distribution of *marram* (a lateritic deposit) within the area will be of great interest to students of similar deposits elsewhere. The *marram*, like the Western Australian "ironstone," was formed under conditions of sub-aerial denudation different from the present and is now being destroyed. The paper expresses the rapidity with which our knowledge of the African desert is accumulating. The bibliography shows that the work upon which the map is based was all done within the century, and most of it within the last ten years. M. A.

CORRESPONDENCE

TEMPLE AT ARMANT

There existed at Armant till the year 1861 an extremely interesting temple built by Cleopatra the Great in honour of the birth of her son Caesarion. This was completely demolished between the years 1861 and 1863 and the materials were taken and used in the construction of a sugar factory; but, prior to that date, it had been visited and described by many travellers, and fortunately, a number of drawings, plans, and photographs of it were taken by them. We are engaged upon a reconstruction of this temple for publication and we should be very grateful for any help which your readers may be able to give us, to make this as complete as possible. Any information about unpublished description, plans, drawings or photographs of this temple, or about out-of-the-way published descriptions of it would be of the greatest value.

A large number of travellers toured this part of Egypt in the eighteenth and nineteenth centuries, when the diary habit was strong, the standard of draughtsmanship high, and towards the end of the temple's existence photography was just becoming popular. We believe that there may well remain important records in private collections which would be of great assistance in making some restitution for the vandalism of the last century.

ROBERT MOND
OLIVER H. MYERS

Egypt Exploration Society, 1 *November* 1935.

Passing references are made in travellers' narratives of the eighteenth century to the ruins of Thebes, and some of them mention Erment, an older form of Armant. Richard Pococke, in his 'Description of the East,' 1743, appears to have been the first to have described the ruins of Erment, "which is the antient city Hermonthis," in detail, and to have drawn a plan, which is reproduced in his book. He records that the ante-temple was then very much destroyed: the enclosure around it and the temple "are very particular, but little remains except the foundations. The inner temple is intire. There are stairs up to the top, through the wall, on one side of the building, which is about twenty-five feet high: it is adorn'd with hieroglyphics within and without."

With the military operations in Egypt at the end of the century, interest in the monuments was further stimulated. The scholars who accompanied Napoleon's expedition in 1798–99 studied many of the antiquities; the results were included in the 'Description de l'Egypte,' a work, in twenty-four volumes of text and eleven volumes of plates and maps, which began to appear in 1809, and was completed during the restoration. Seven plates (*Antiquités*, vol. 1, nos. 91–7) are given to Erment: in addition to views of the ruins, they include a general plan of the locality, plans and elevations of the temple, and engravings of the bas-reliefs. The text contains a description of the ruins, and discusses at some length the stone tank or basin to the south. No conclusive evidence was obtained to support the theory that this had served as a Nilometer. English travellers were also attracted by these monuments. Among the lithographs from drawings by Major Charles Hayes, of the Royal Engineers, which accompany William Hamilton's 'Aegyptiaca,' is one of the front elevation of the temple of Hermonthis, probably done in 1801. "The body of the temple he visited here," says Hamilton, "is still entire—some of the columns are fallen down."

Belyoni's 'Plates illustrative of researches . . . in Egypt and Nubia,' 1822,

contains a coloured lithograph of "the temple at Erments." It is a cruder drawing than Hayes', from which it differs in one or two details. A small sketch of the side elevation is in Roberts' 'Egypt and Nubia,' vol. 2, published in 1849, though the sketch is dated 1838. Roberts records that "upon the roof of the *naos* is the residence of the Sheik of Erment, and every available spot within and about the Temple is occupied by the mud-huts of the inhabitants." Details of its final destruction, with a small sketch, are given by G. Ebers in his description of Egypt, of which an English translation was published in 1880. The books quoted in this note are in the Society's Library.

MEETINGS: SESSION 1935–36

Third Evening Meeting, 21 November 1935. Admiral Sir William Goodenough in the Chair

Paper: The Country and People of the Central New Guinea Highlands. By Mr. Michael Leahy

Fourth Evening Meeting, 2 December 1935. The President in the Chair

Elections: William Henry Cotton; Major-General Sir Henry Leycester Croker, K.C.B., C.M.G.; Mrs. William Hunt; Gordon Leslie Isaac; Sir Algernon Law, K.C.M.G., C.B.; Marco Pallis; Frederick Gordon Pearce, B.A.; Walter Harold George Popplestone; Edward Colman Rashleigh; Reverend Denzil G. Ridout; Thomas Vincent Sheppard, M.SC.; R. H. Stevenson; Sydney Arnold Thomas; Frederick Edward Milan Thrupp, M.I.E.E., A.M.I.MECH.E.; James Eric Vine

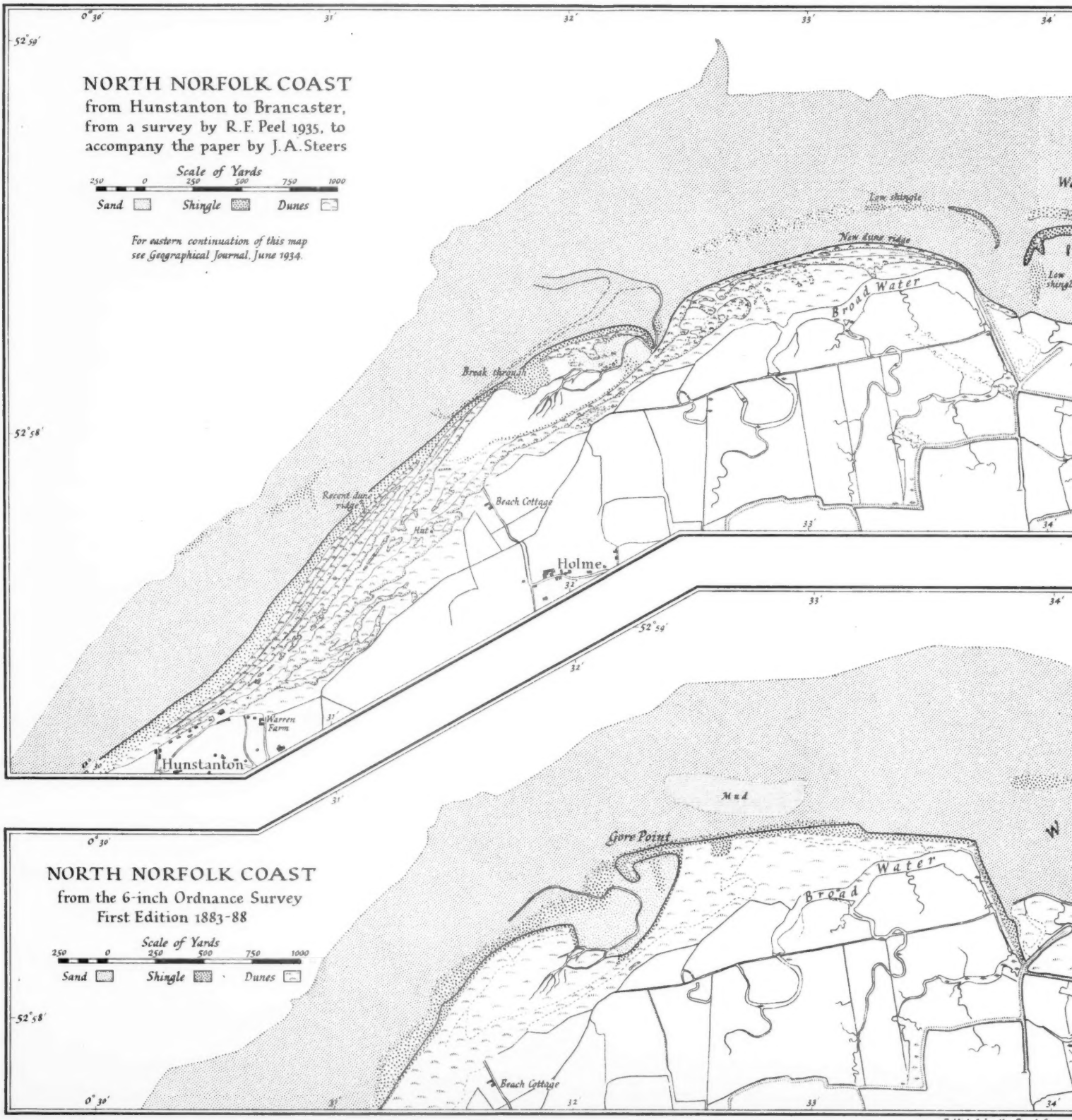
Paper: The Mount Everest Reconnaissance 1935. By Mr. Eric Shipton

Second Afternoon Meeting, 9 December 1935. Discussion of Ordnance Survey Maps, opened by the President

Fifth Evening Meeting, 16 December 1935. The President in the Chair

Elections: John Loftas Backhouse; William Gordon Tredinnick Brooks, B.A.; Alan Brown; Karthy Velayut Widya Dharan, B.SC.; Doctor Charles Fenner; Lieut. Christopher Francis Fothergill; Charles Hubbard; Miss Violet Hudson; The Princess Despina Karadja; Miss Patricia Barbara Lapworth, B.A.; Captain Angus MacLennan; Miss Sybil Notley, M.A.; Reverend E. M. O'Brien; John Warneford Parker; Doctor William Alfred Richardson, O.B.E., B.A., F.G.S.; Arthur Rye; Mrs. Doris Shuttleworth; Harrison Oakley Smith; Lieut. Leslie Thurston Tomes; W. L. Williamson

Paper: Two Months in the Hadhramaut. By Miss Freya Stark



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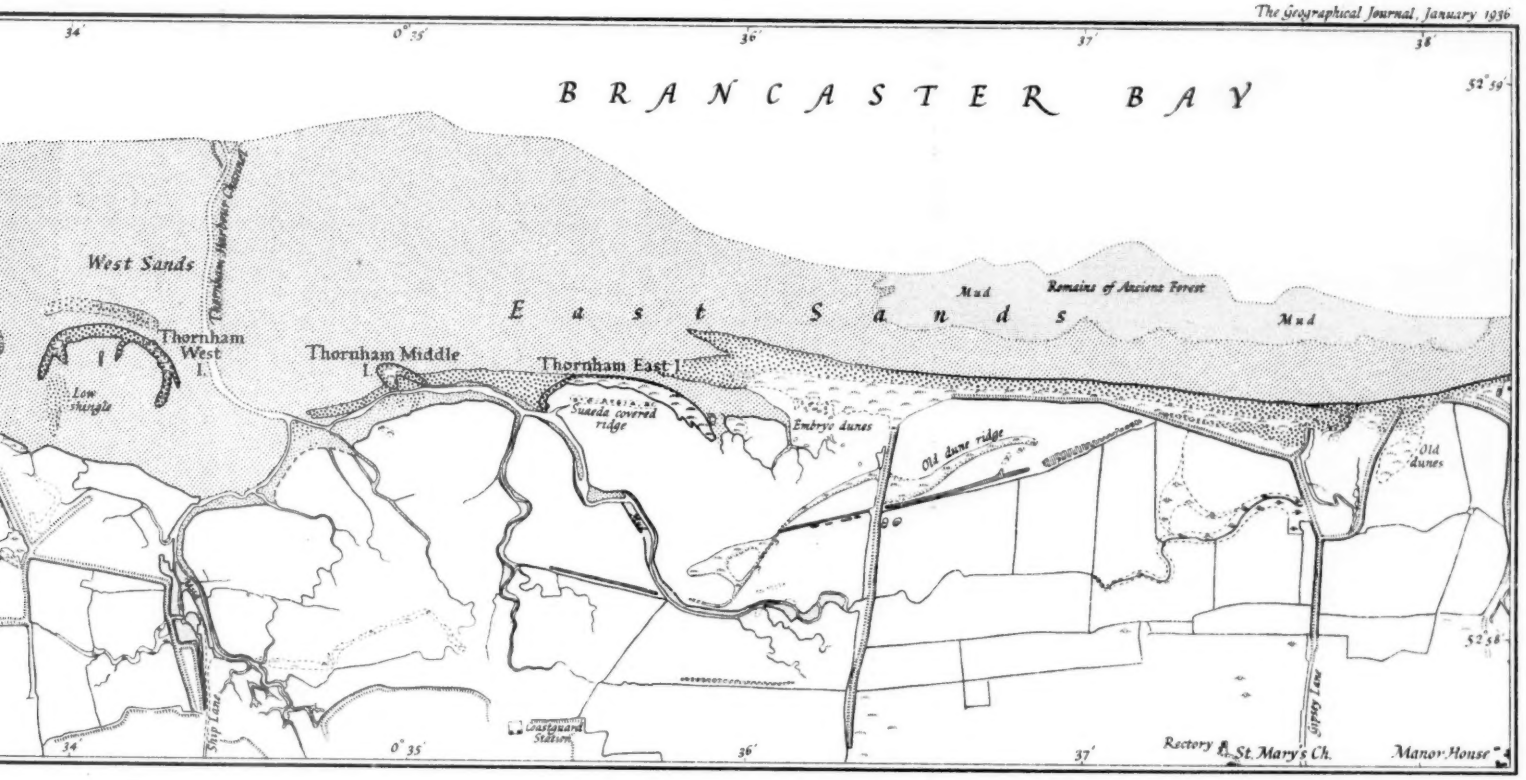

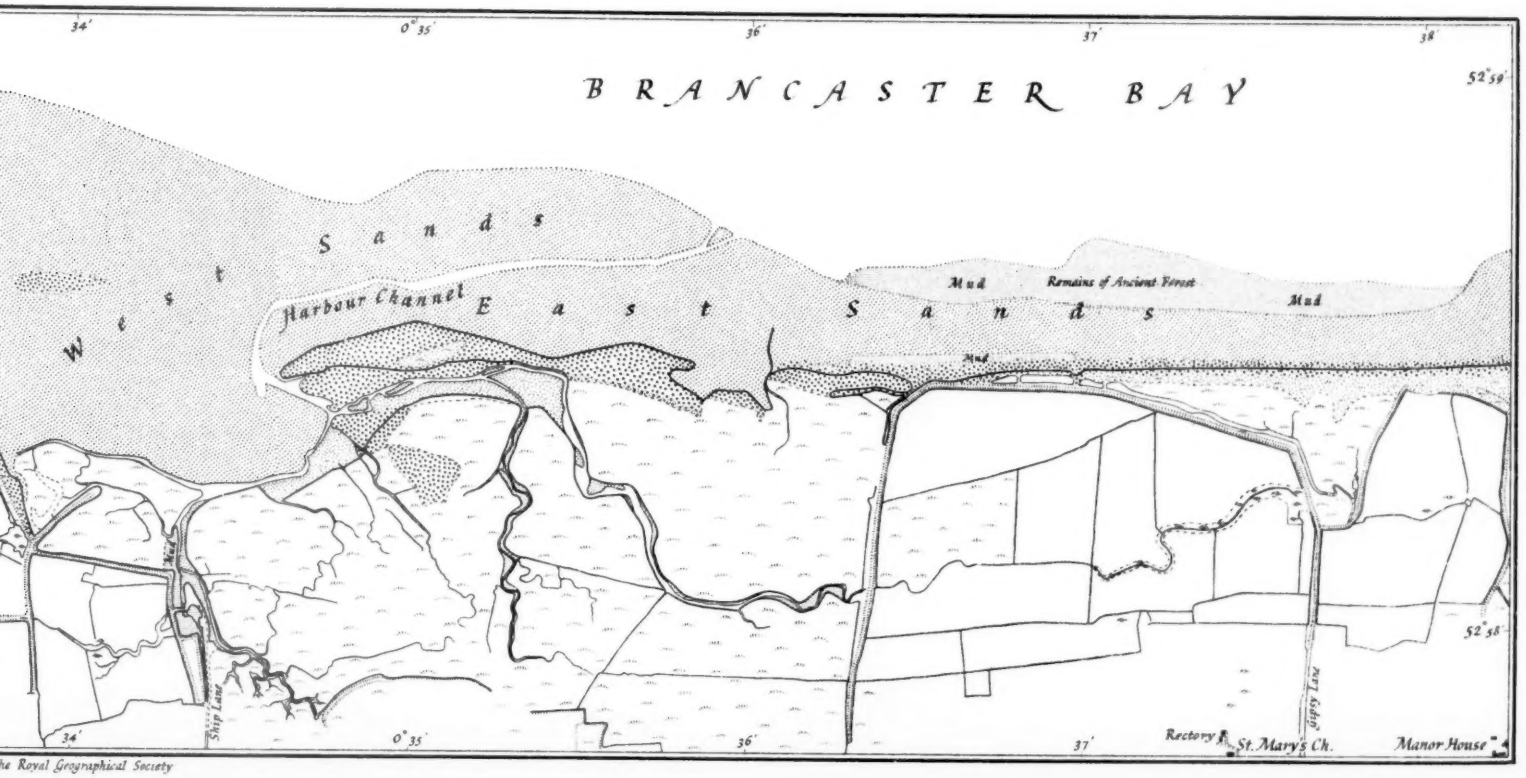

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